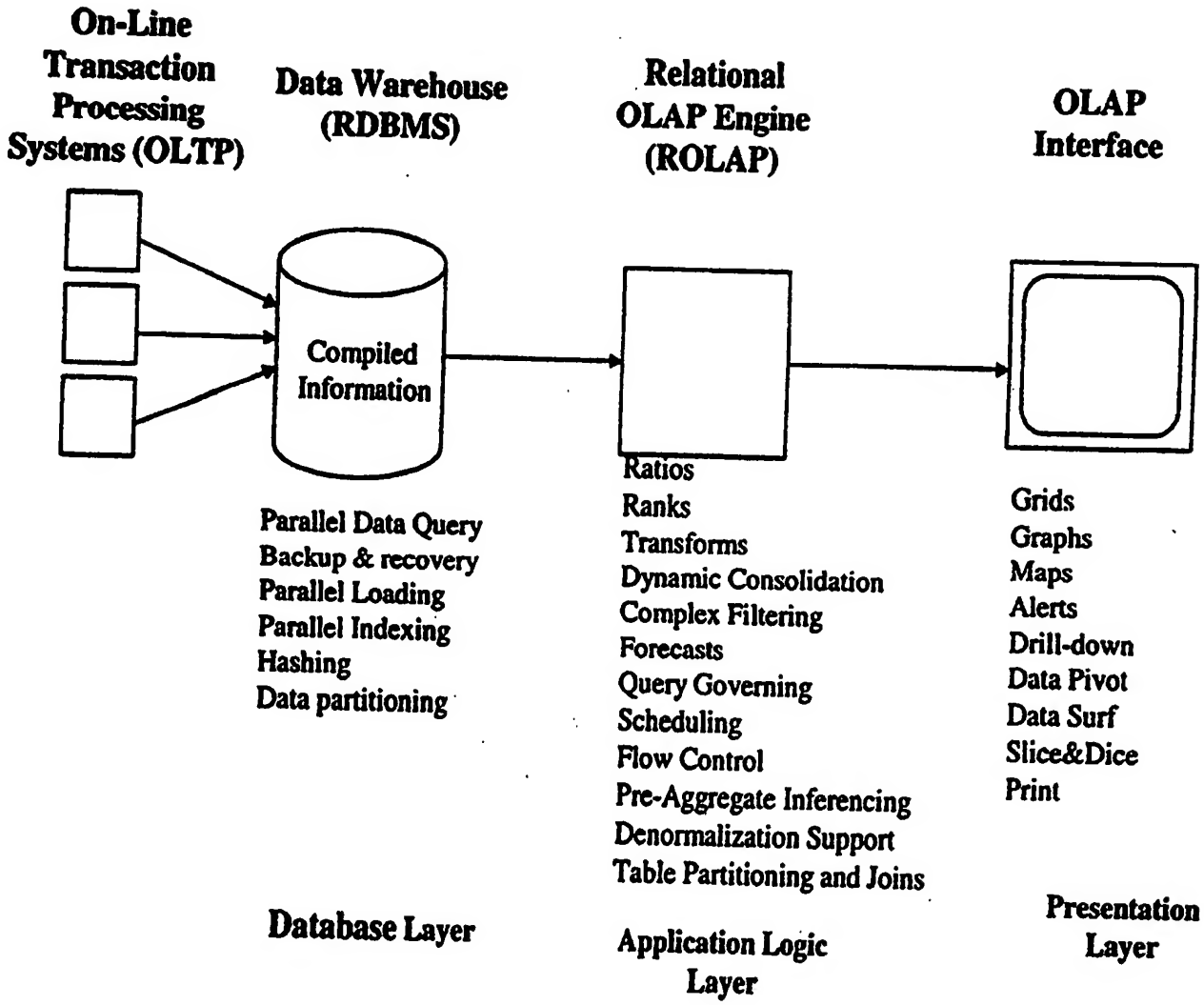


Fig.1A
(PRIOR ART)

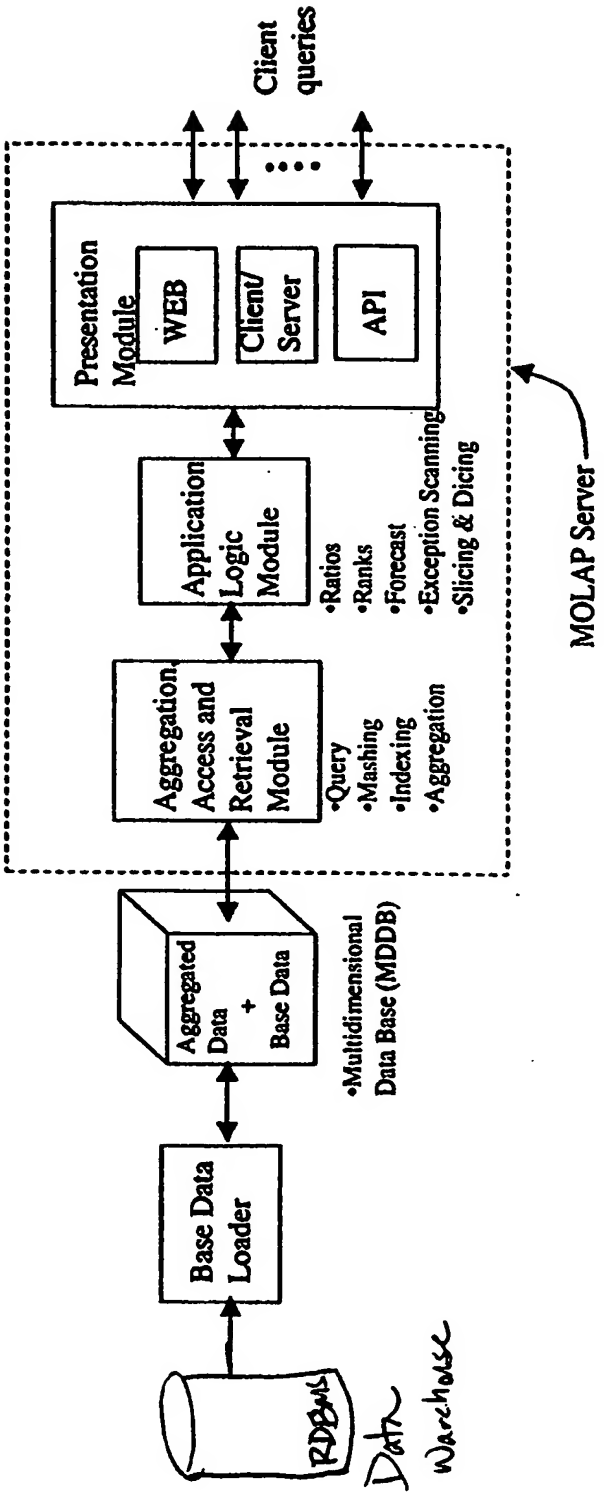

Client queries
Presentation Module
WEB
Client/ Server
API
Application Logic Module
•Ratios
•Ranks
•Forecast
•Exception Scanning
•Slicing & Dicing
Aggregation Access and Retrieval Module
•Query
•Mashing
•Indexing
•Aggregation
MOLAP Server
Aggregated Data + Base Data
•Multidimensional Data Base (MDDB)
Base Data Loader
RDBMS
Data Warehouse

FIG. 1B

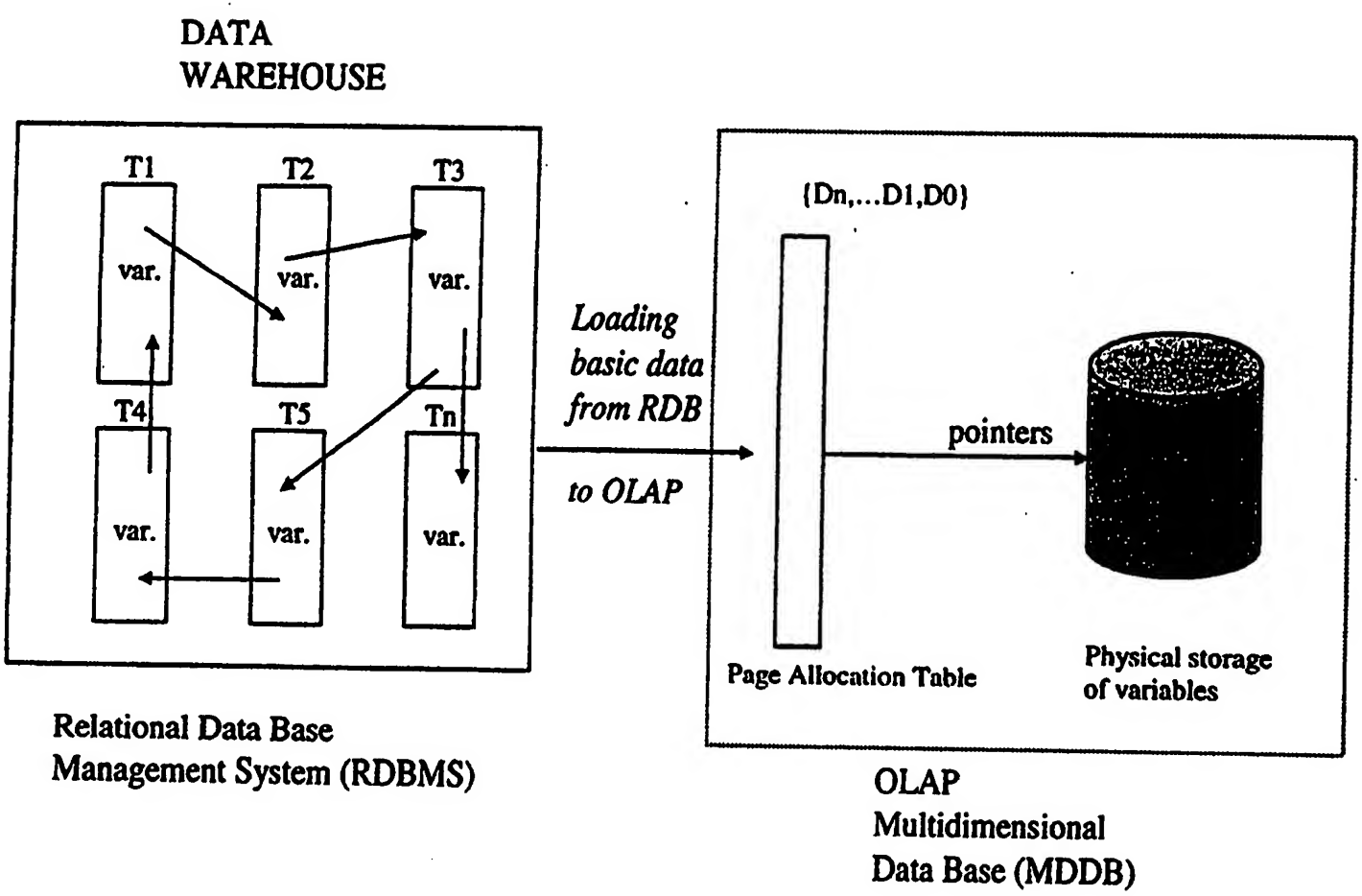
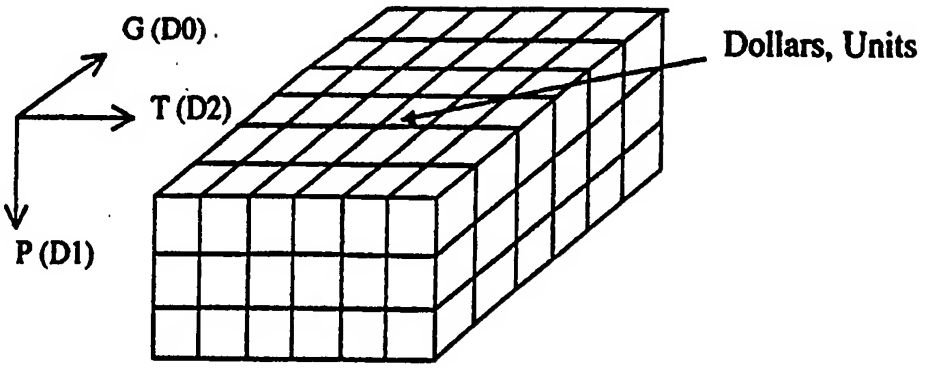


Fig. 2A
(PRIOR ART)



G	geography (e.g. cities, states, countries, continents)
T	time (e.g., days, weeks, months, years)
P	products (e.g. all products, by manufacturer)

Fig. 2B
(PRIOR ART)

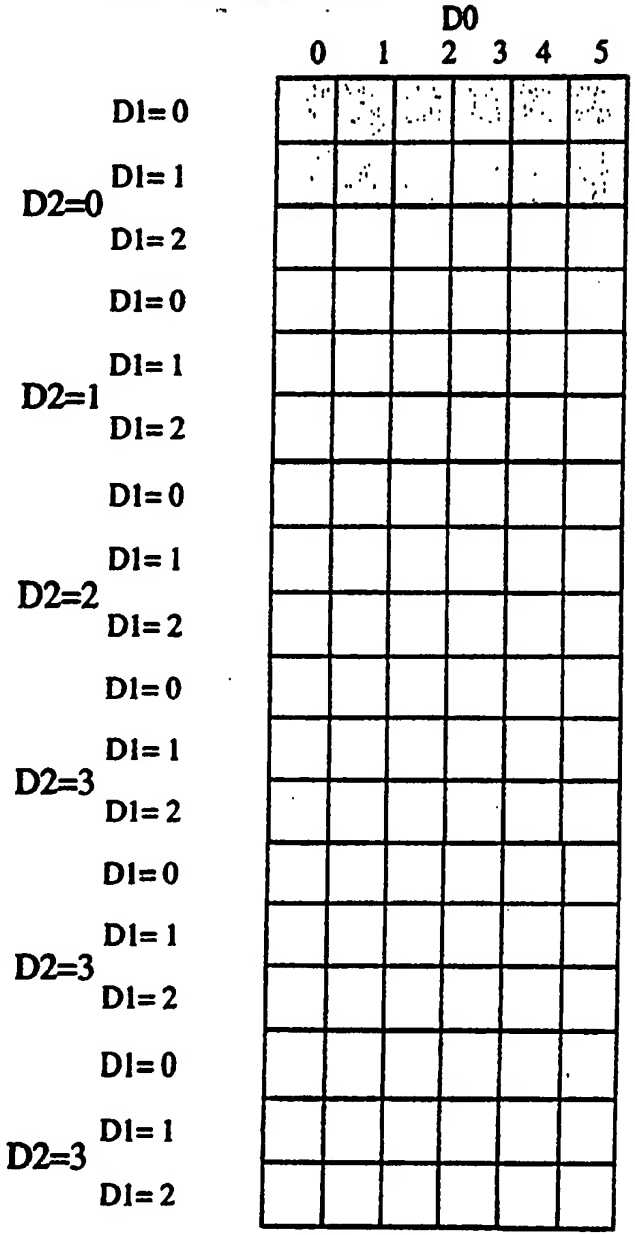


Fig. 2C

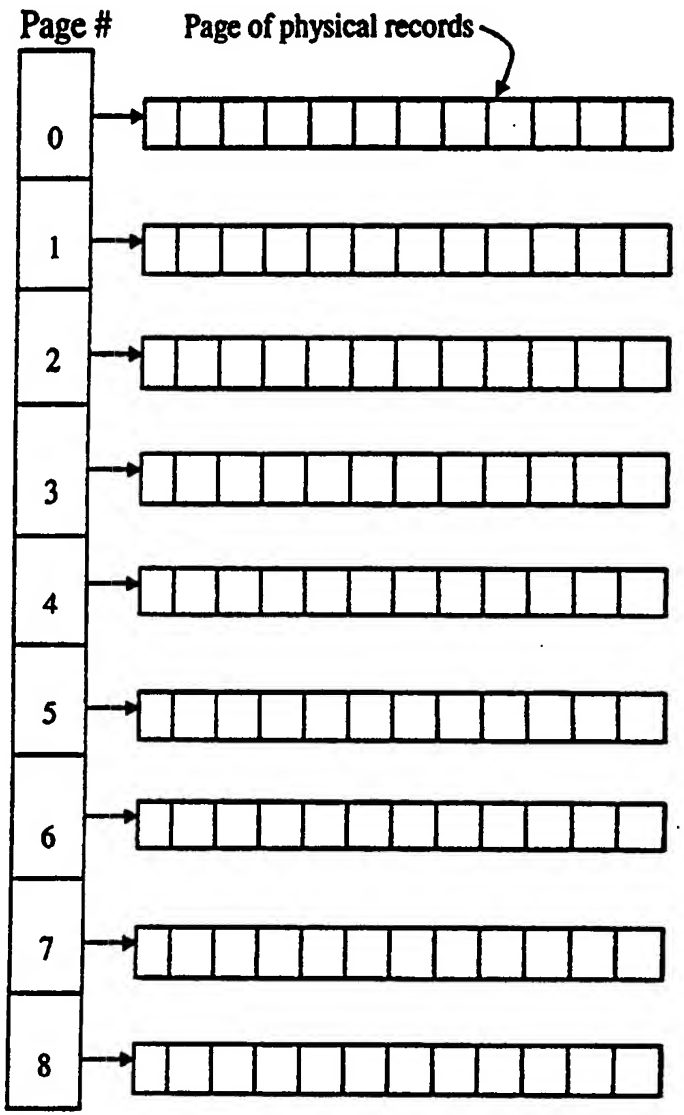
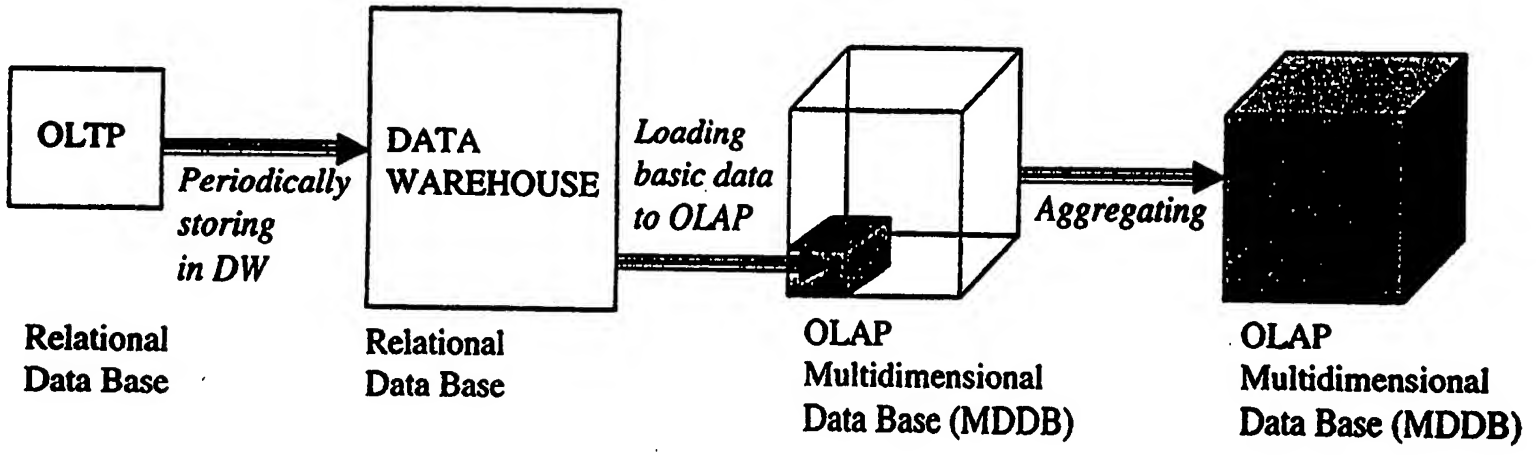


Fig. 2D
(PRIOR ART)



6/49

Fig. 3A
(PRIOR ART)

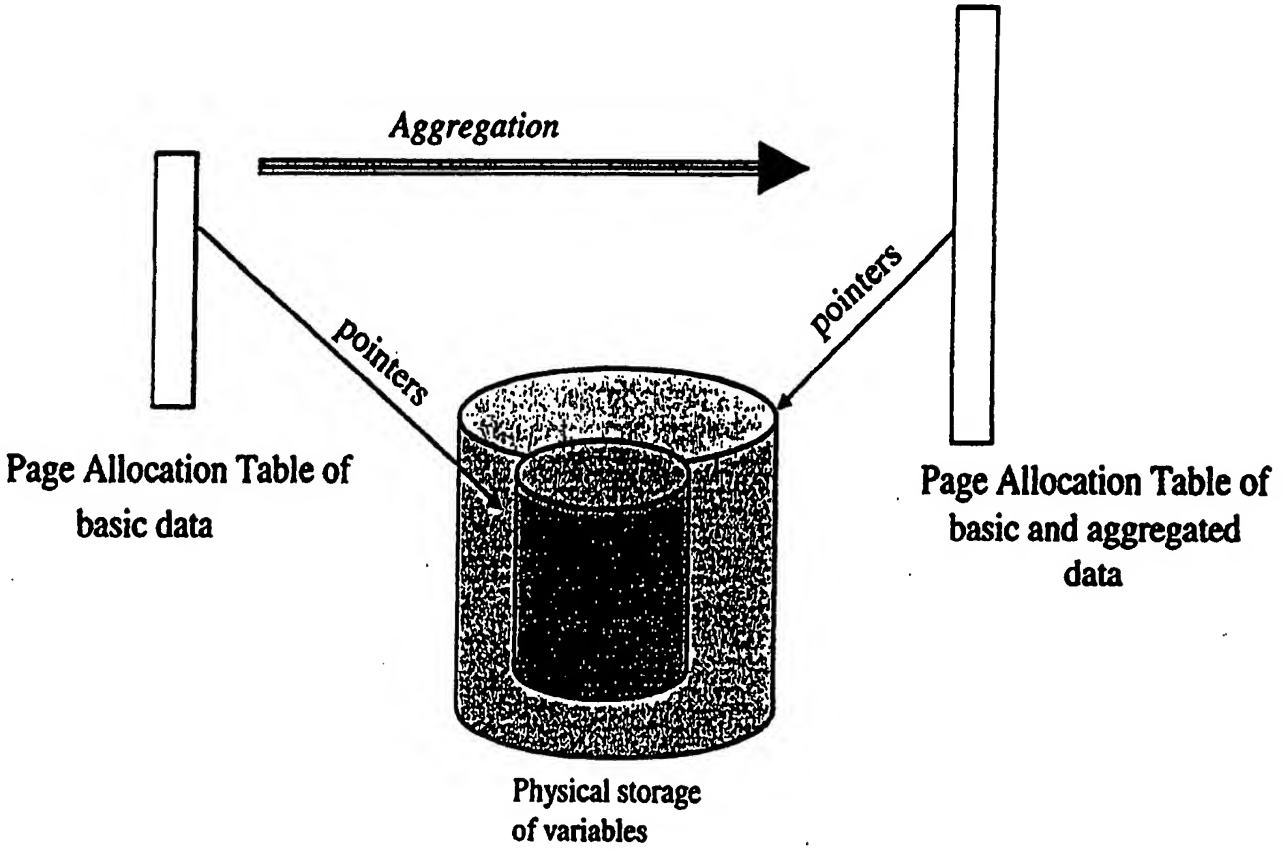


Fig. 3B
(PRIOR ART)

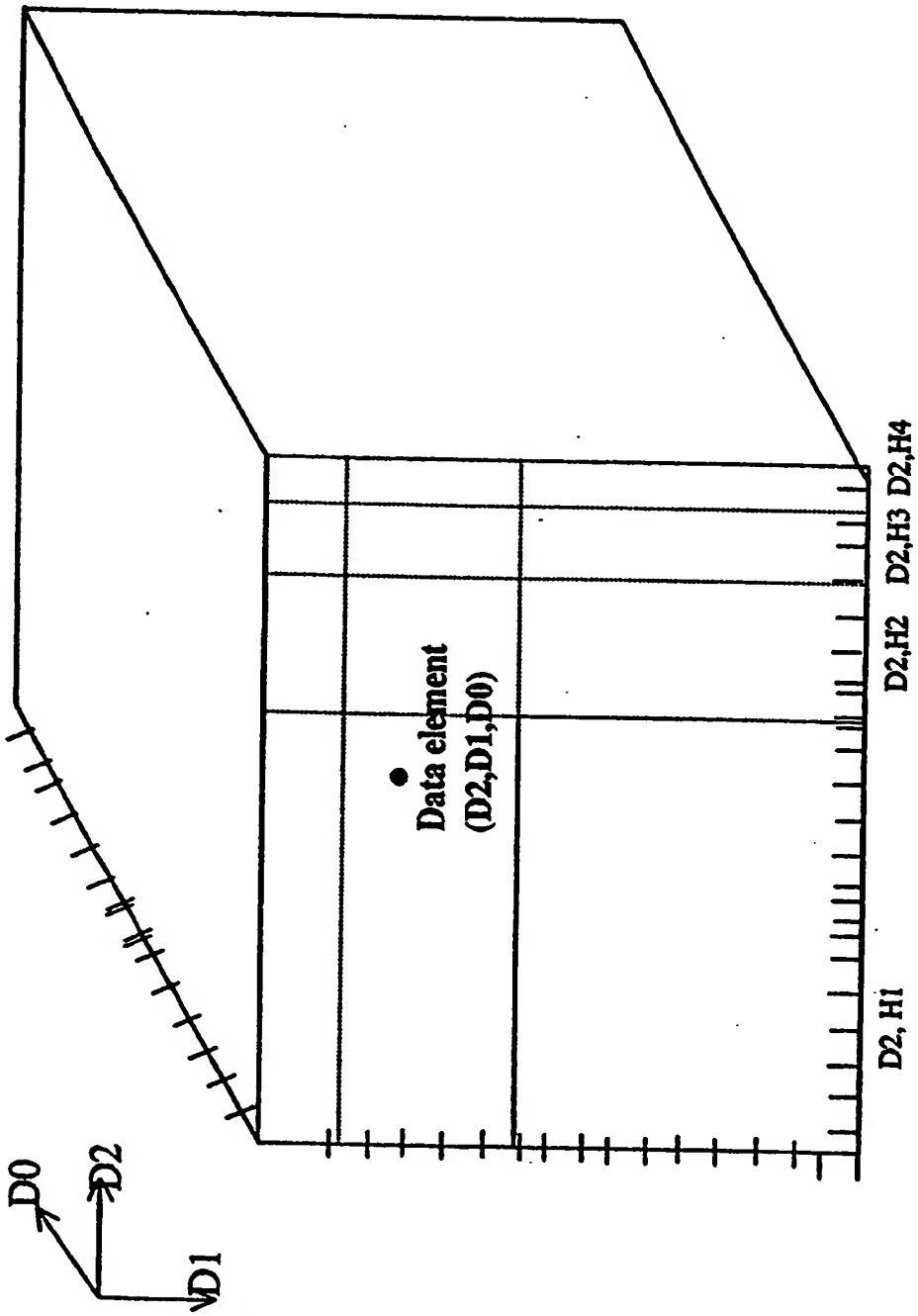
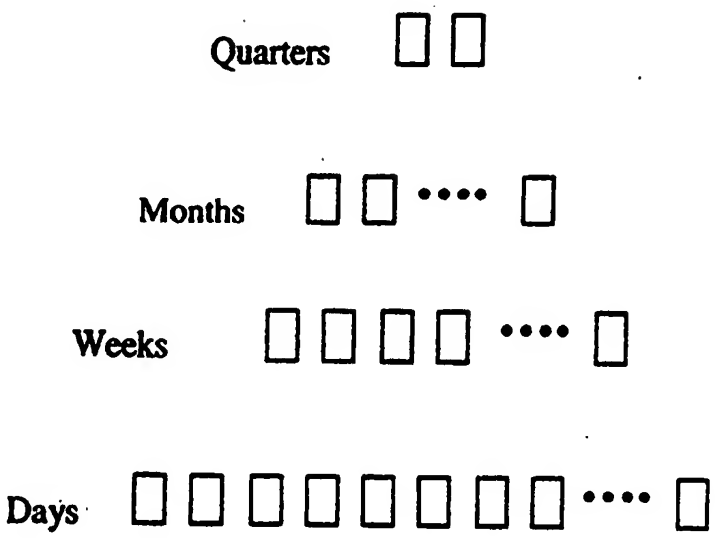
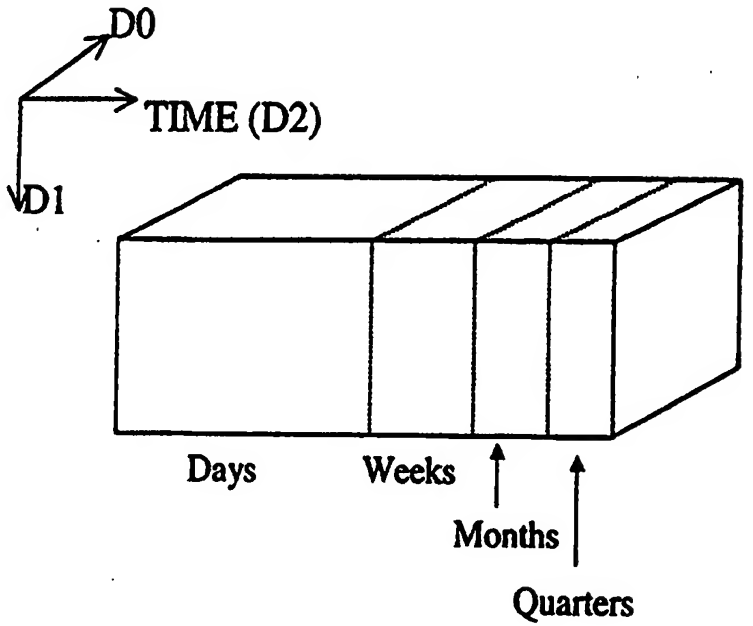


Fig. 3C1
(PRIOR ART)



Hierarchy of TIME dimension

Fig. 3C2
(PRIOR ART)



Spatial occupancy of TIME hierarchy

Fig. 3C3
(PRIOR ART)

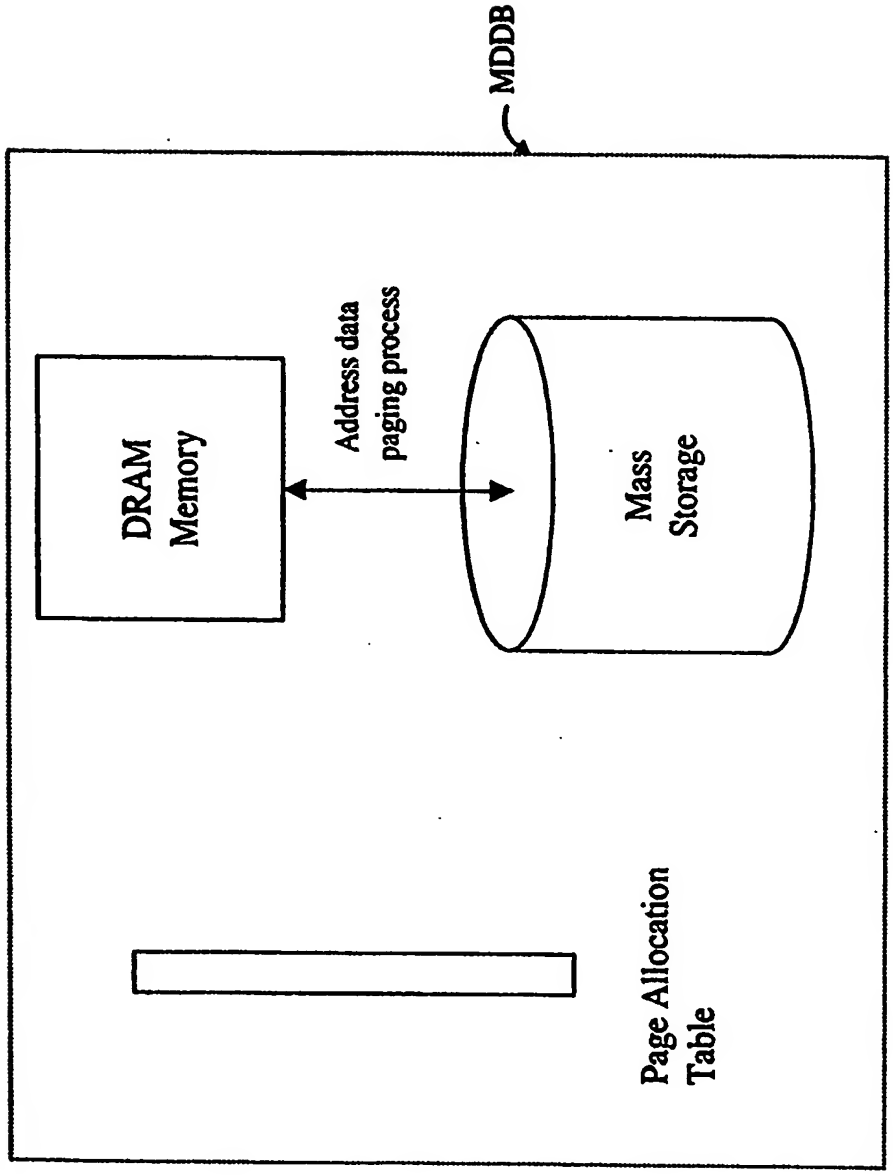


Fig. 4
(PRIOR ART)

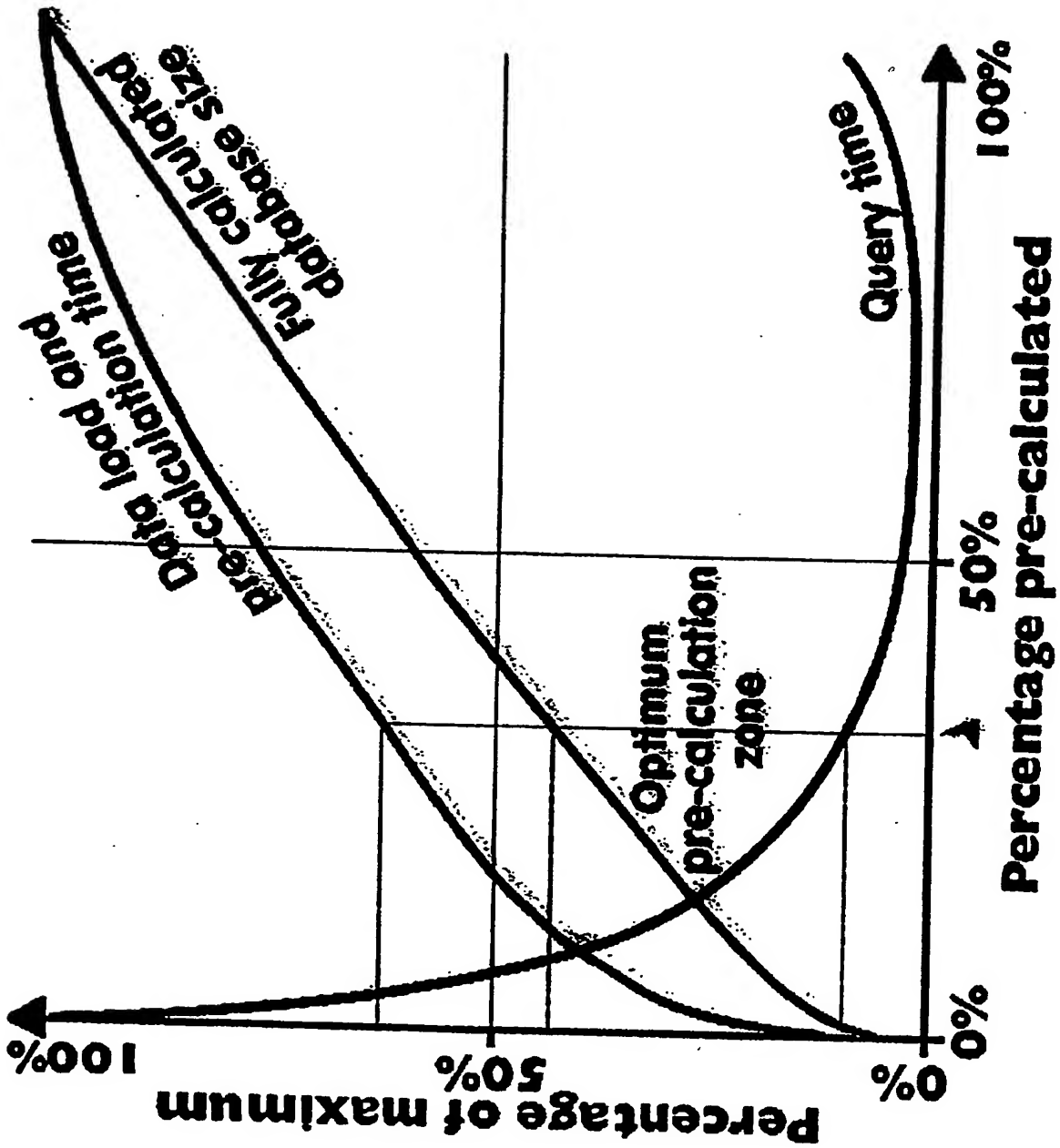


Fig. 5
(PRIOR ART)

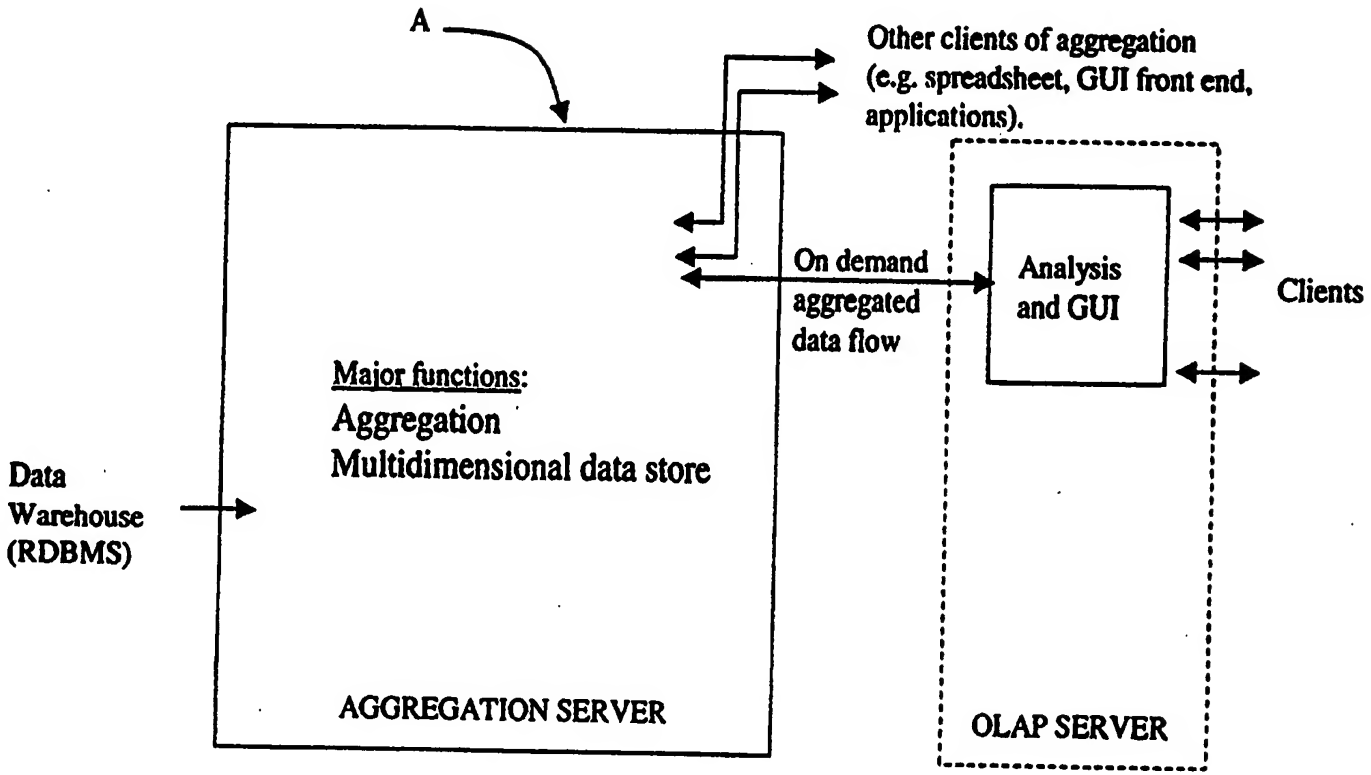

A
Other clients of aggregation
(e.g. spreadsheet, GUI front end,
applications).
On demand
aggregated
data flow
Analysis
and GUI
Clients
Major functions:
Aggregation
Multidimensional data store
Data
Warehouse
(RDBMS)
AGGREGATION SERVER
OLAP SERVER

Fig. 6A

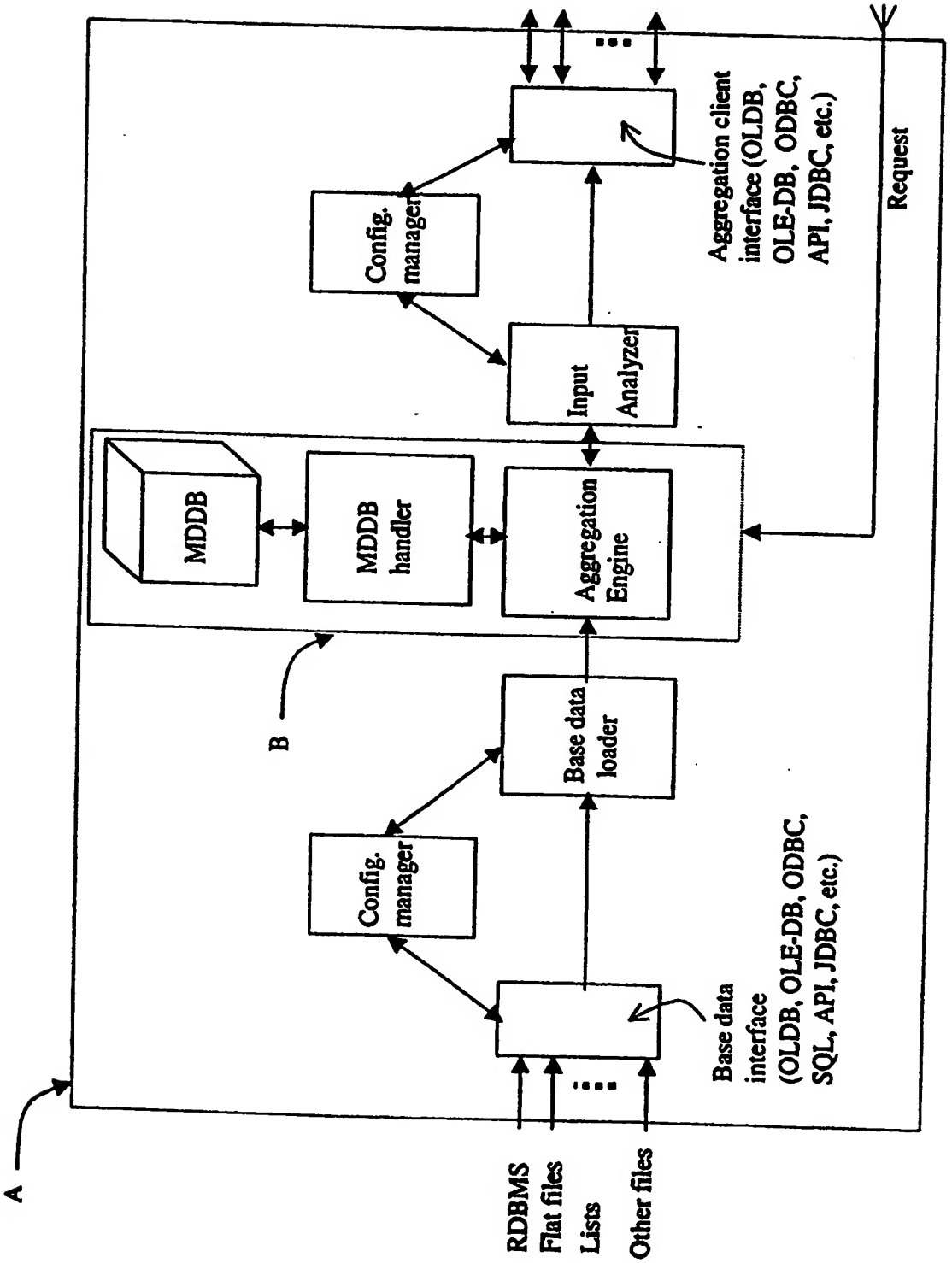

A
RDBMS
Flat files
Lists
Other files
Base data interface (OLDB, OLE-DB, ODBC, SQL, API, JDBC, etc.)
Config. manager
Base data loader
B
MDDB
MDDB handler
Aggregation Engine
Input Analyzer
Config. manager
Aggregation client interface (OLDB, OLE-DB, ODBC, API, JDBC, etc.)
Request

Fig. 6B

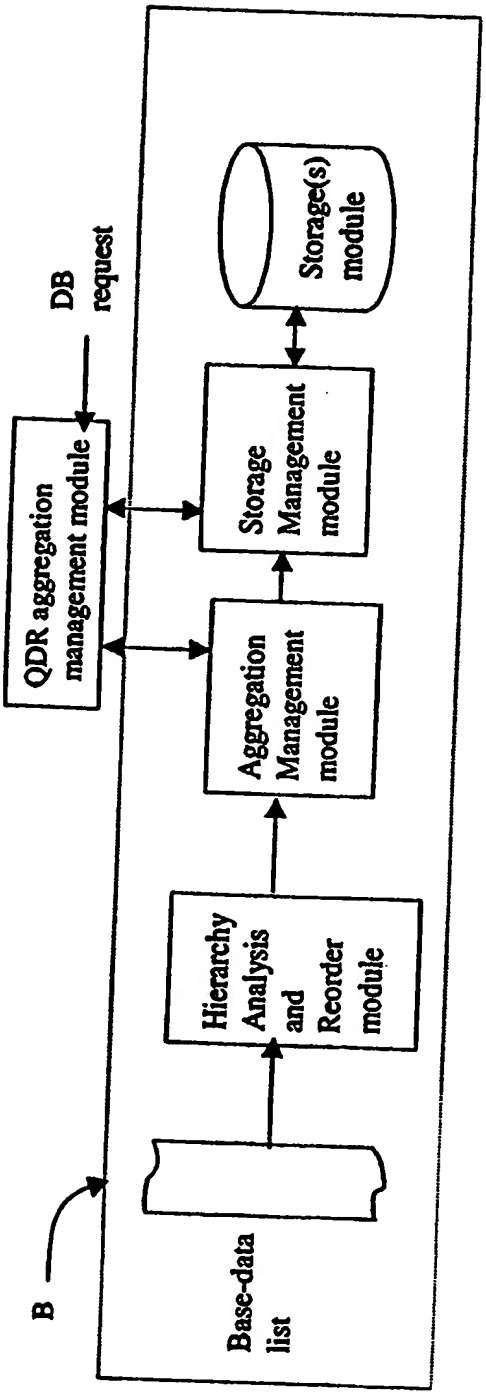

B
Base-data list
Hierarchy Analysis and Reorder module
Aggregation Management module
Storage Management module
Storage(s) module
QDR aggregation management module
DB request

Fig. 6C

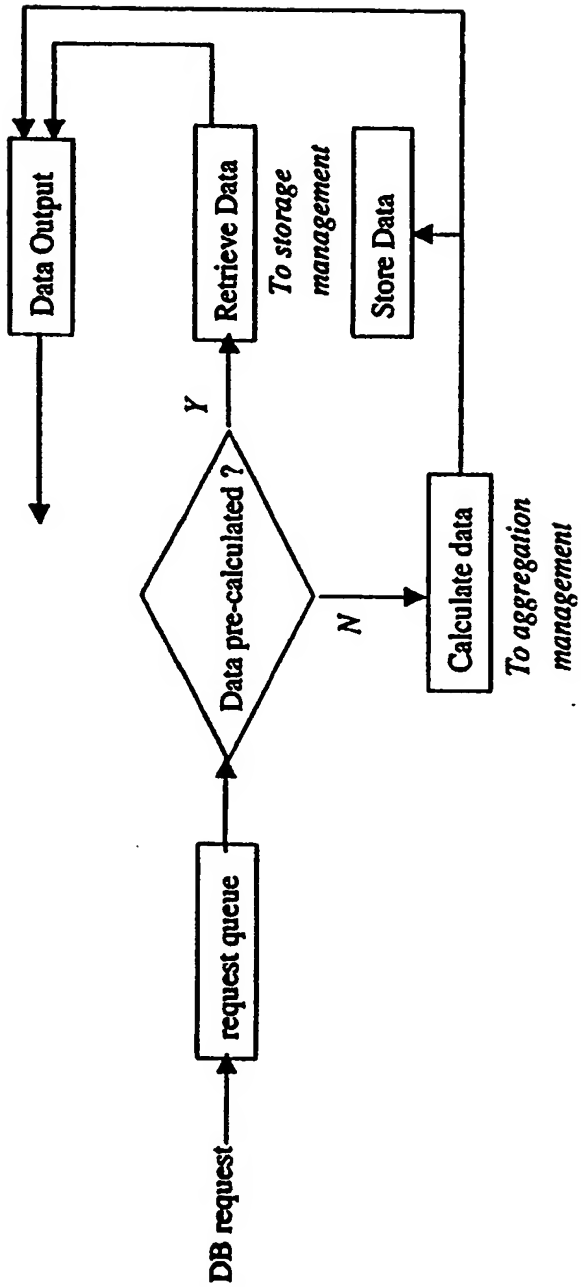

DB request
request queue
Data pre-calculated ?
Y
N
Retrieve Data
To storage management
Store Data
Calculate data
To aggregation management
Data Output

Fig. 6D

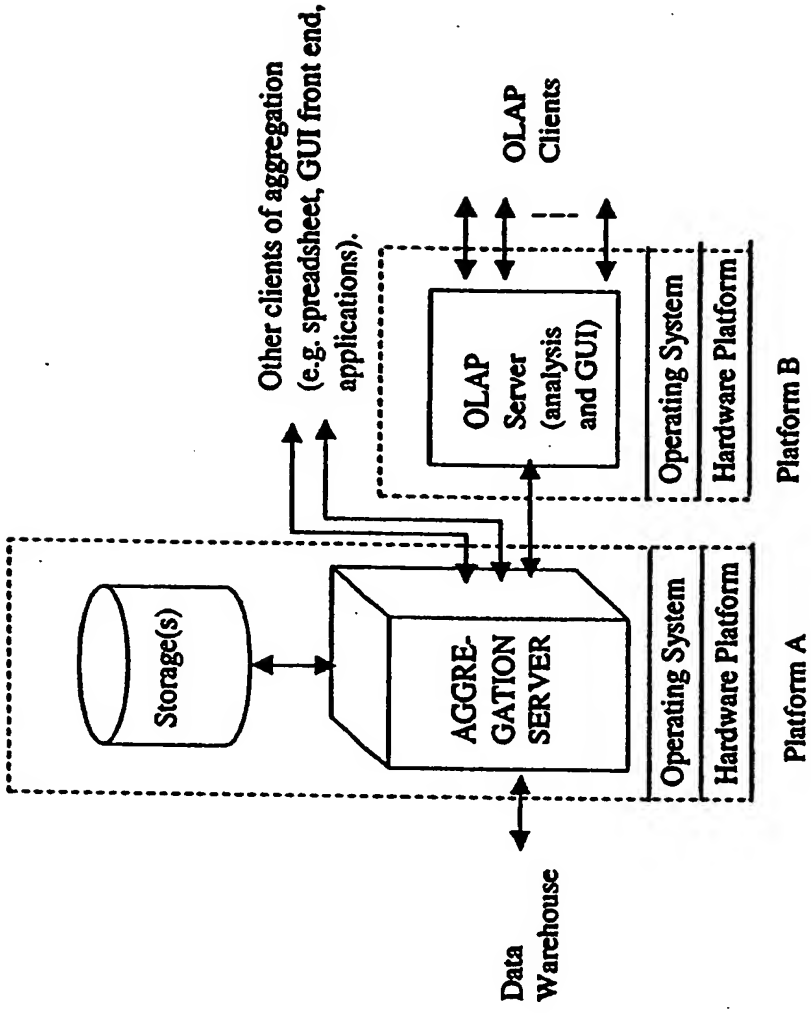

Other clients of aggregation
(e.g. spreadsheet, GUI front end,
applications).
OLAP
Clients
OLAP
Server
(analysis
and GUI)
Operating System
Hardware Platform
Platform B
Storage(s)
AGGRE-
GATION
SERVER
Operating System
Hardware Platform
Platform A
Data
Warehouse

Fig. 7A

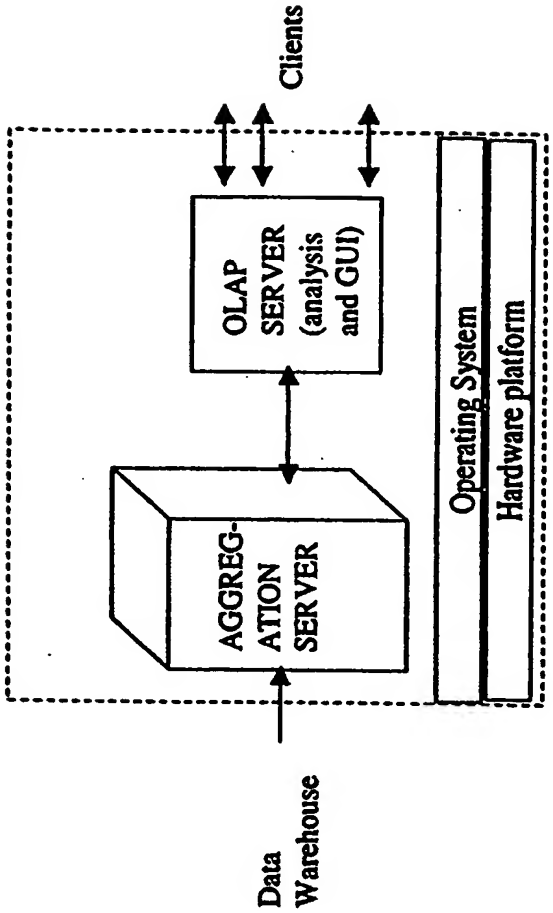

Clients
OLAP SERVER (analysis and GUI)
AGGREG-ATION SERVER
Operating System
Hardware platform
Data Warehouse

Fig. 7B

	Nbr of Dim.	Nbr. of atomic data values	Leaf node density %	Number of values in cube after roll-up	Oracle EXPRESS v. 6.2	Implementation of current invention
D1	6	302 M	9	427 M	16 h	15 m
D2	4	414 M	1.27	969 M	50 m	5 m
D3	5	14,499 M	0.03	63,954 M	31 h	1h 23m
D4	6	623,494 M	$8*10^{-4}$	7,930 G	Exceeds 48h	2h 20m
D5	6	243,000 G	10^{-5}	1,160,000 G	22 h	4 m
D6	4	7 M	defined as 100	19 M	15 m	1 m

Fig. 8A

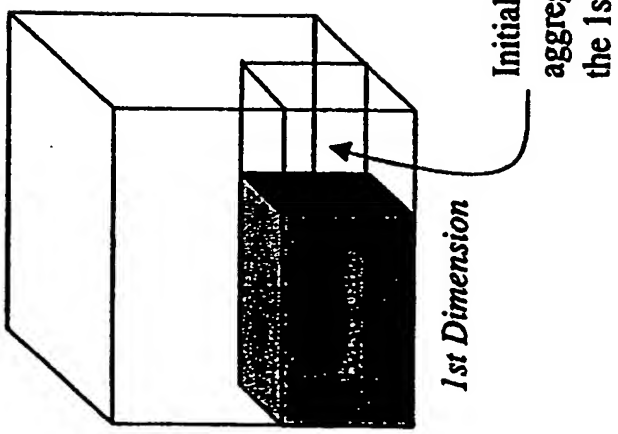


Fig. 9A

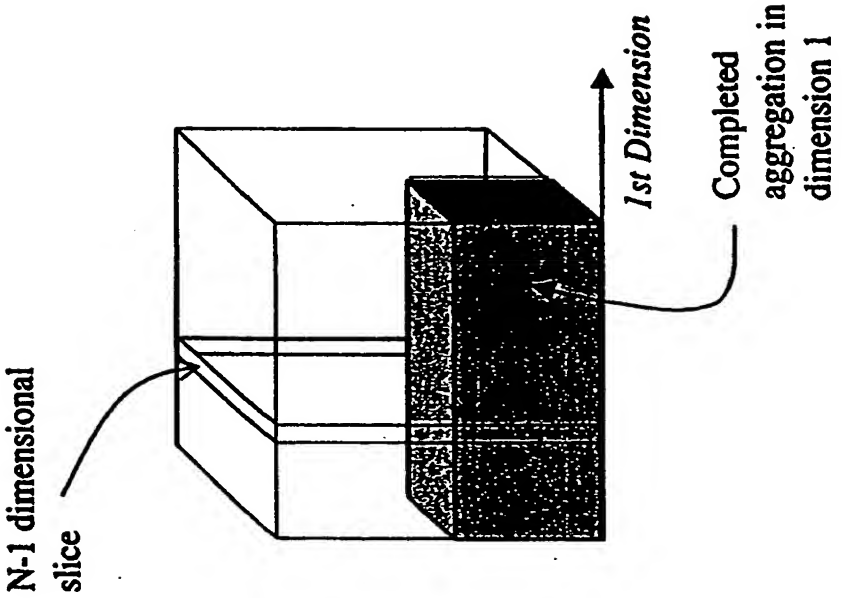
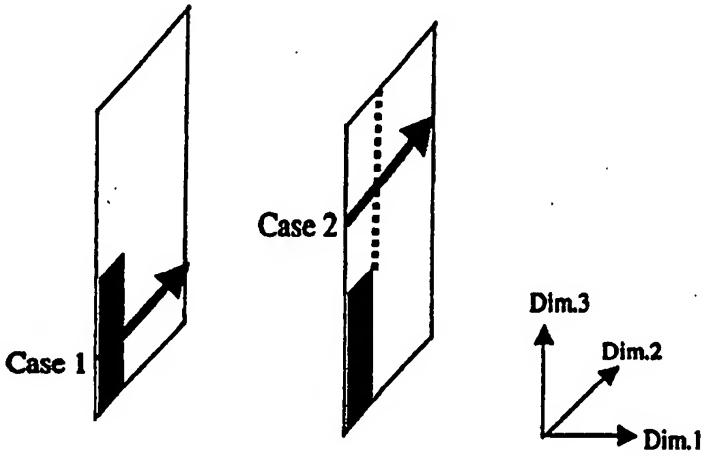
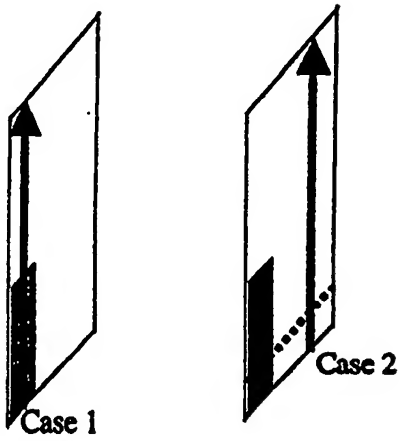

N-1 dimensional slice
1st Dimension
Completed aggregation in dimension 1

Fig. 9B



a. Directed aggregation
in dimension 2, cases 1 and 2.

Fig. 9C1



b. Directed aggregation
in dimension 3, cases 1 and 2.

Fig. 9C2

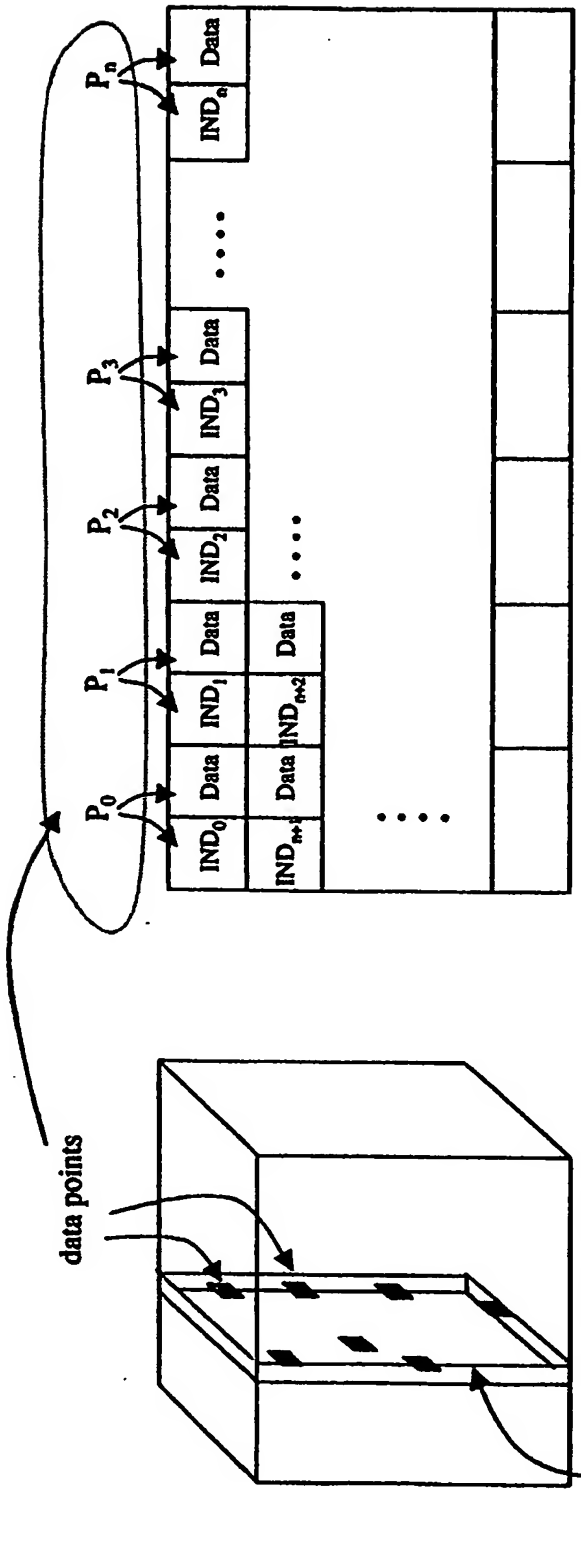

P0
P1
P2
P3
Pn
IND0
Data
IND1
IND2
IND3
INDn
INDn+1
INDn+2
data points
1st Dimension
A unit-wide
MDB slice
DATA FILE

Fig. 10A

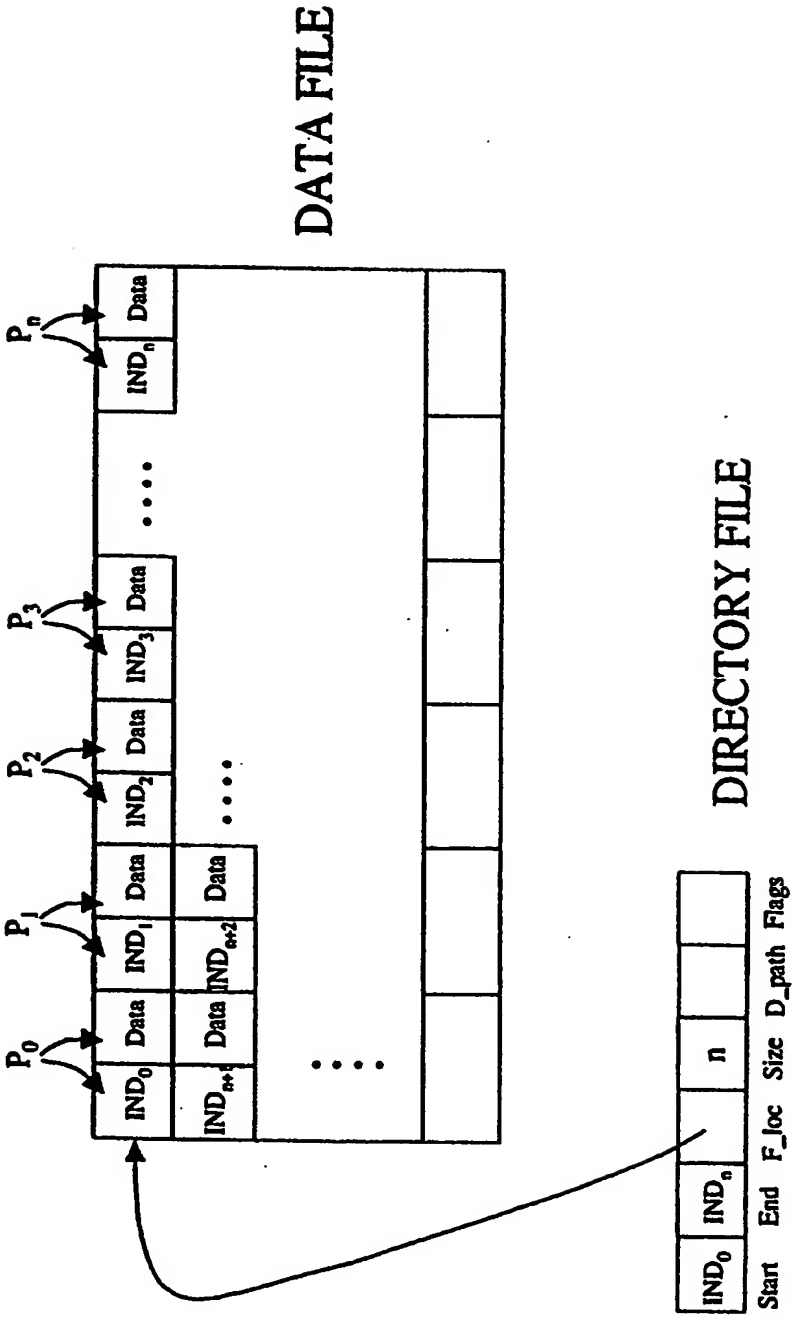

DATA FILE
DIRECTORY FILE
P0
P1
P2
P3
Pn
IND0
IND1
IND2
IND3
INDn
IND n+1
IND n+2
Data
Start
End
F_loc
Size
D_path
Flags
n

Fig. 10B

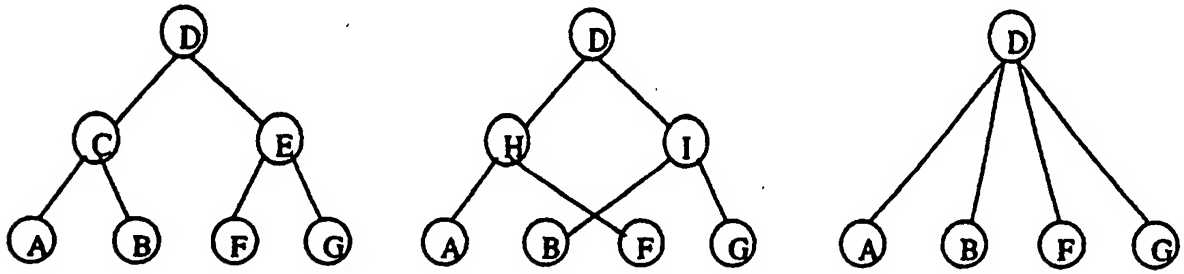


Fig. 11A

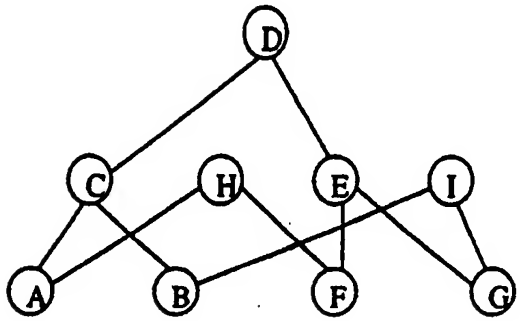


Fig. 11B

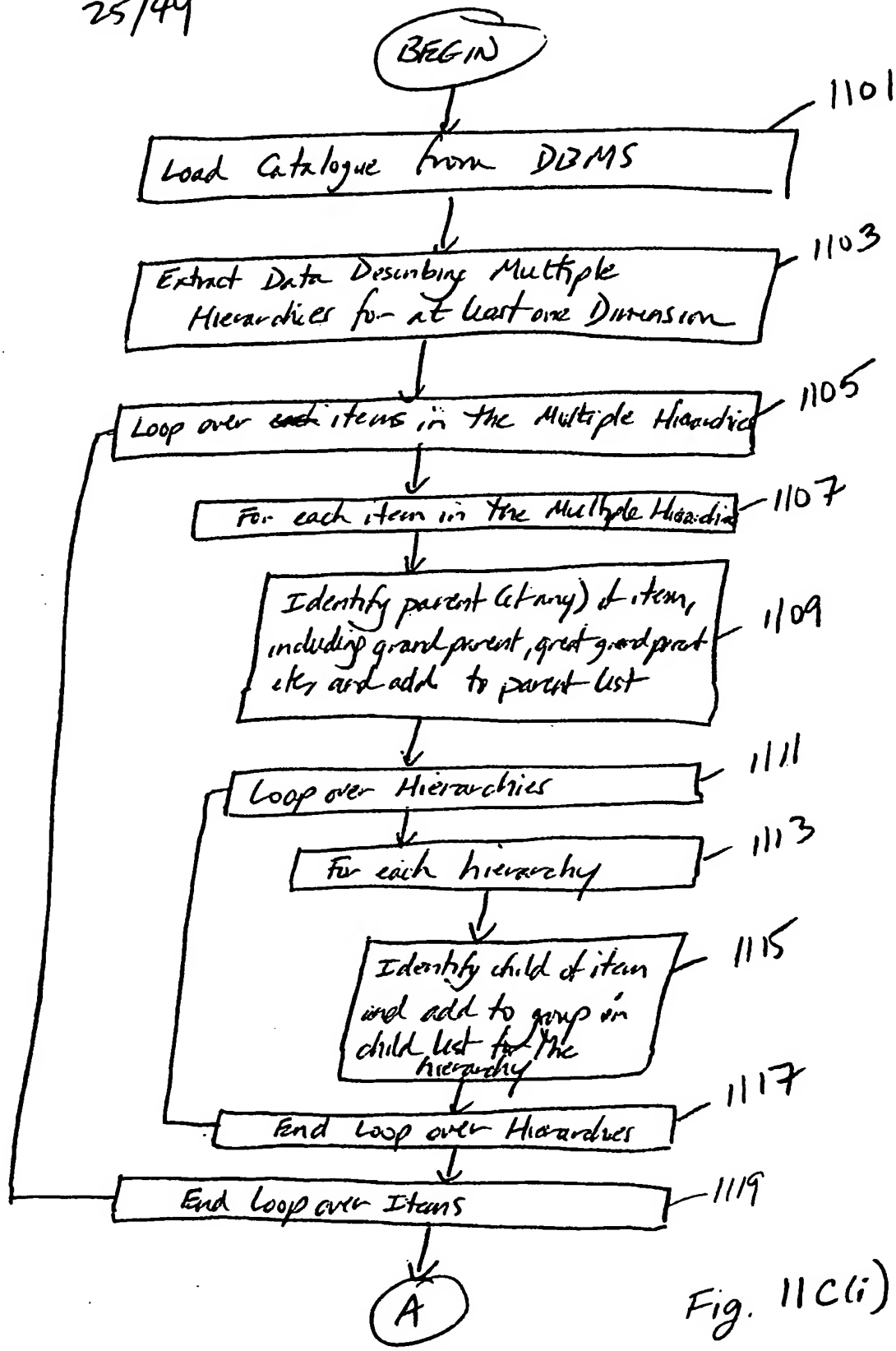

BEGIN
1101
Load Catalogue from DBMS
1103
Extract Data Describing Multiple Hierarchies for at least one Dimension
1105
Loop over each item in the Multiple Hierarchies
1107
For each item in the Multiple Hierarchies
1109
Identify parent (if any) of item, including grandparent, great grandparent etc and add to parent list
1111
Loop over Hierarchies
1113
For each hierarchy
1115
Identify child of item and add to group in child list for the hierarchy
1117
End Loop over Hierarchies
1119
End Loop over Items
A

Fig. 11C(i)

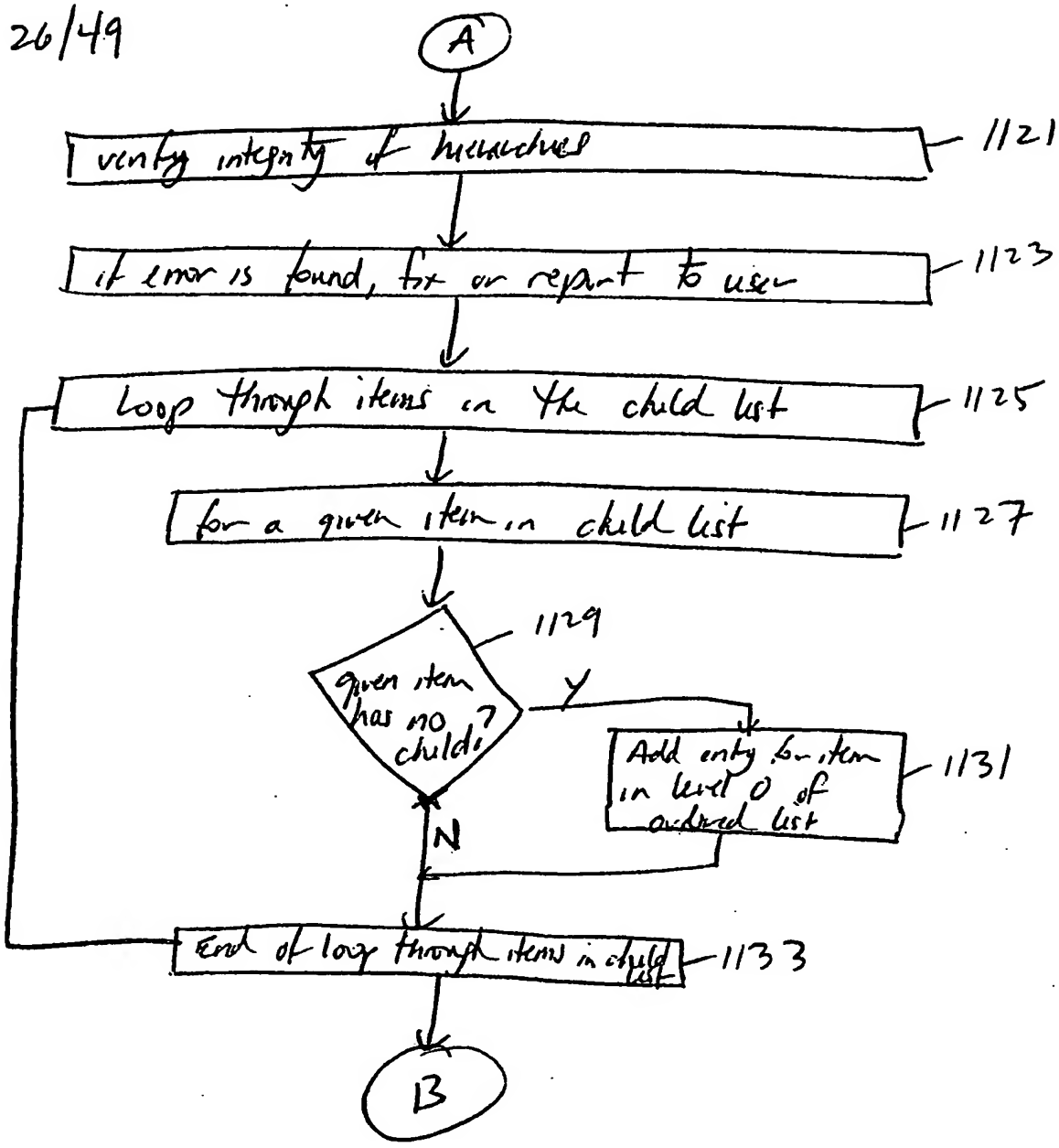

A
verify integrity of hierarchies
1121
if error is found, fix or report to user
1123
Loop through items in the child list
1125
for a given item in child list
1127
1129
given item has no child?
Y
N
Add entry for item in level 0 of ordered list
1131
End of loop through items in child list
1133
B

Fig. 11C(ii)

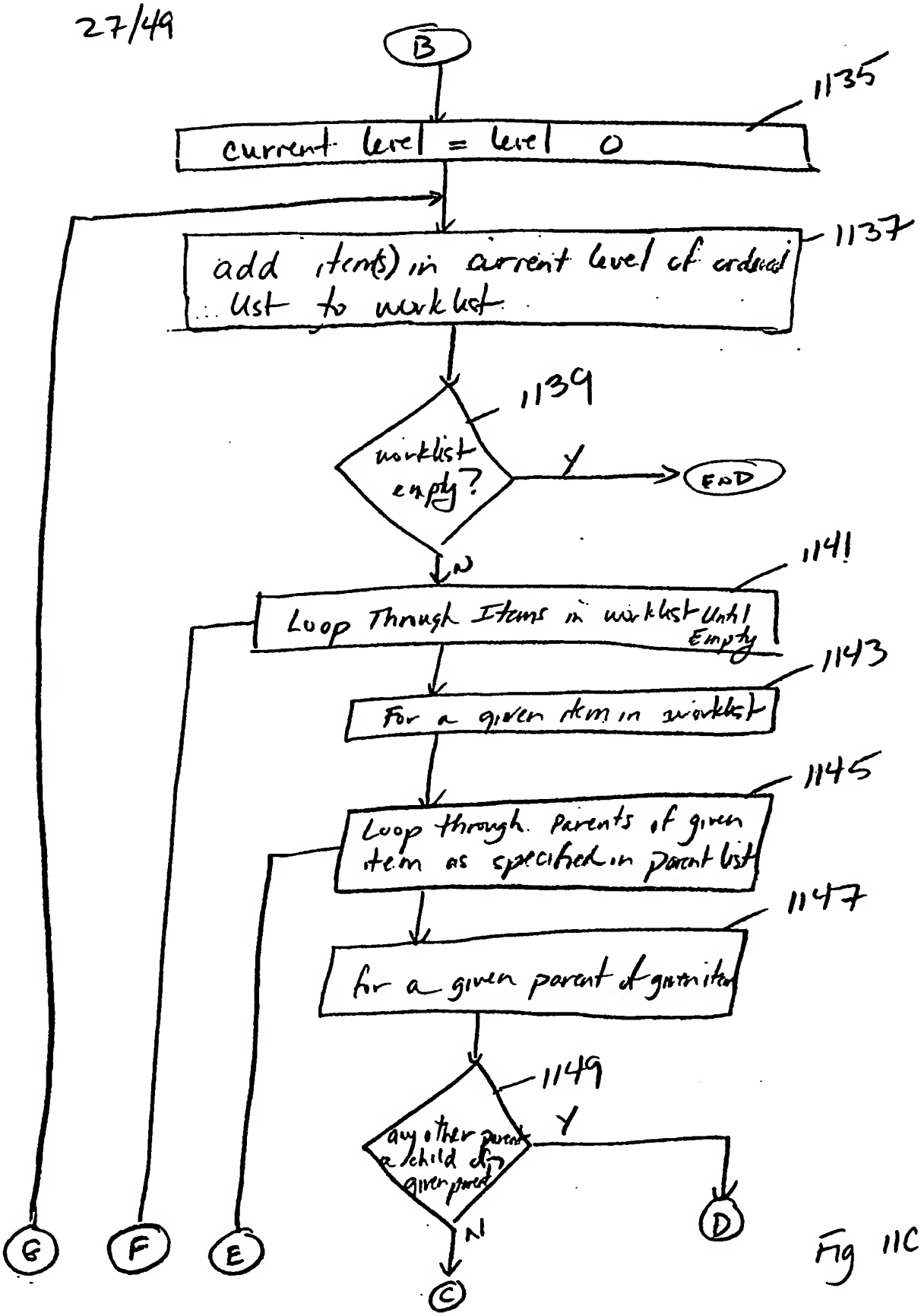

B
1135
current level = level 0
1137
add item(s) in current level of ordered list to worklist
1139
worklist empty?
Y
END
N
1141
Loop Through Items in worklist Until Empty
1143
For a given item in worklist
1145
Loop through parents of given item as specified in parent list
1147
for a given parent of given item
1149
any other parents a child of given parent
Y
N
G
F
E
D
C

Fig 11C(iii

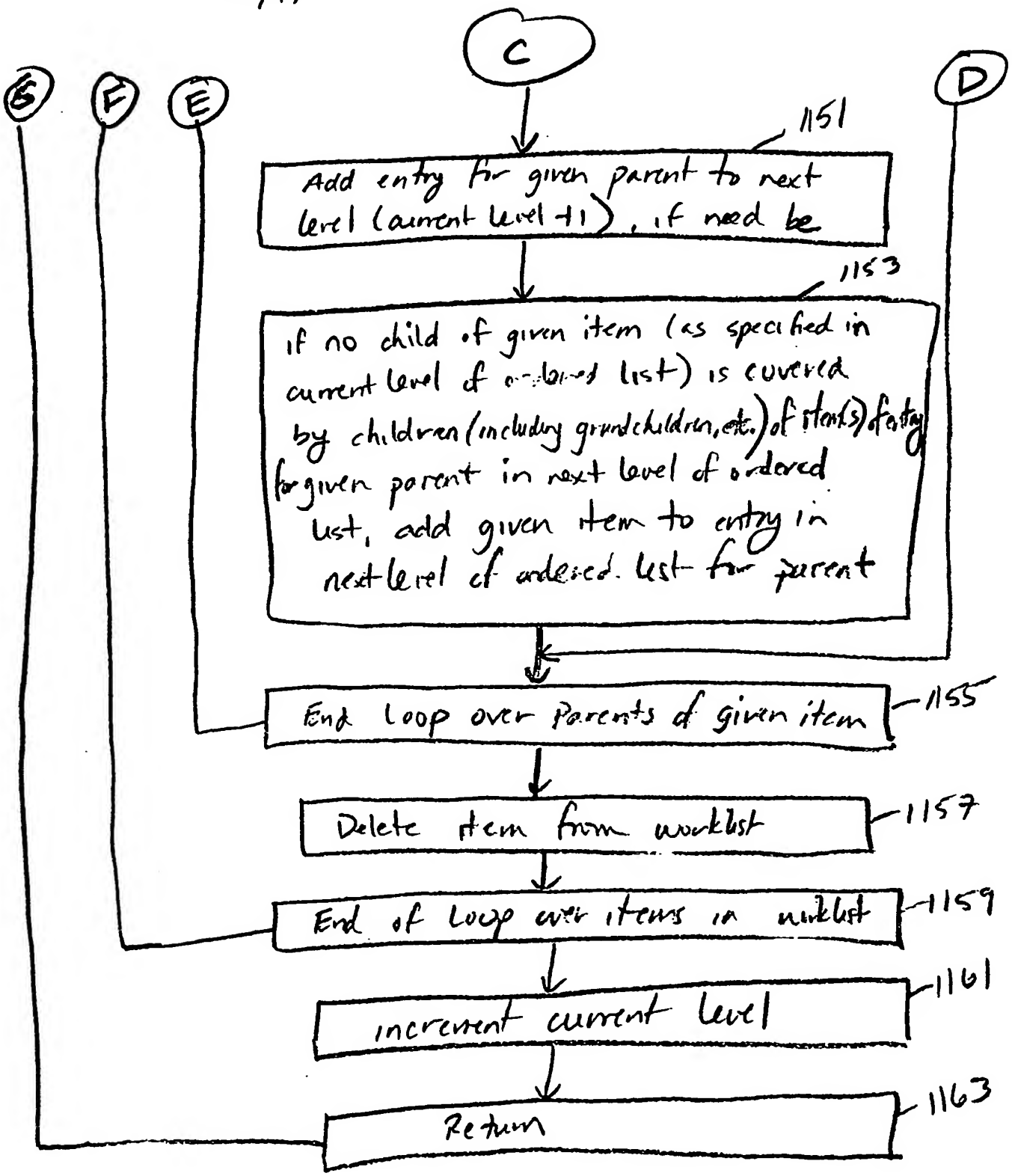

C
D
E
F
G
1151
Add entry for given parent to next level (current level +1), if need be
1153
if no child of given item (as specified in current level of ordered list) is covered by children (including grandchildren, etc.) of item(s) of entry for given parent in next level of ordered list, add given item to entry in next level of ordered list for parent
End loop over parents of given item
1155
Delete item from worklist
1157
End of Loop over items in worklist
1159
increment current level
1161
Return
1163

FIG. 11C(iv)

Parent List

Item	Parent(s)
A	C, H, D
B	C, I, D
F	E, H, D
G	E, I, D
C	D
H	D
E	D
I	D
D	—

FIG 11C(v)

ild List

Item	Child(ren)
A	—
B	—
F	—
G	—
C	<A, B>
H	<F, G>
E	<A, F>
I	<B, G>
D	<A, B, F, C>, <H, I>, <C, E>

Fig 11C(vi)

Ordered List

Level 0

Item	Children)
A	—
B	—
F	—
G	—

FIG. 11C(vii)

Level 1

Item	Children)
C	A, B
H	A, F
I	B, G
E	F, G

FIG. 11C(viii)

Level 2

Item	Children)
D	C, E

FIG. 11C(ix)

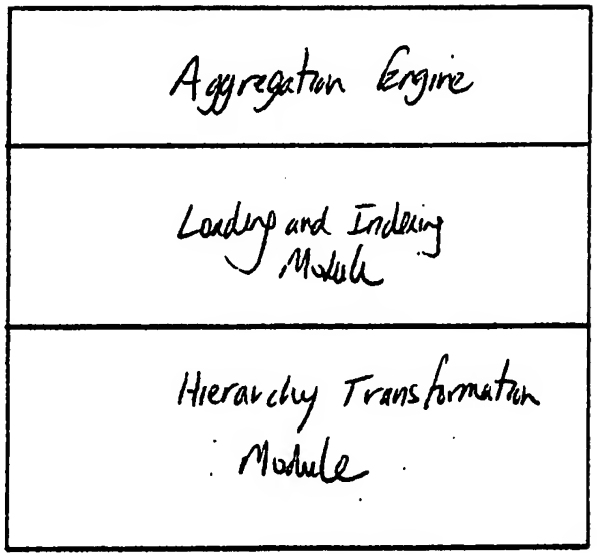

Aggregation Engine
Loading and Indexing Module
Hierarchy Transformation Module

Fig. 12

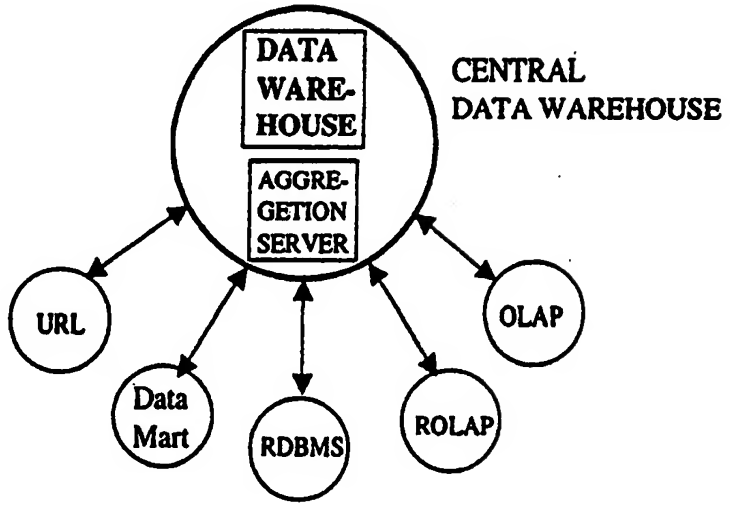
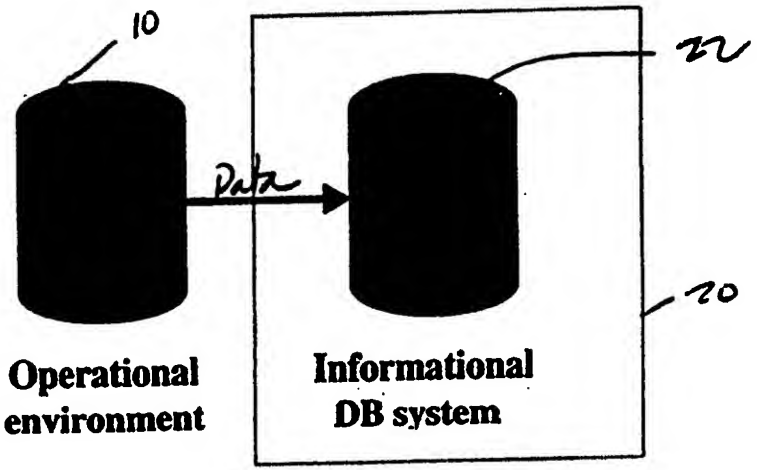
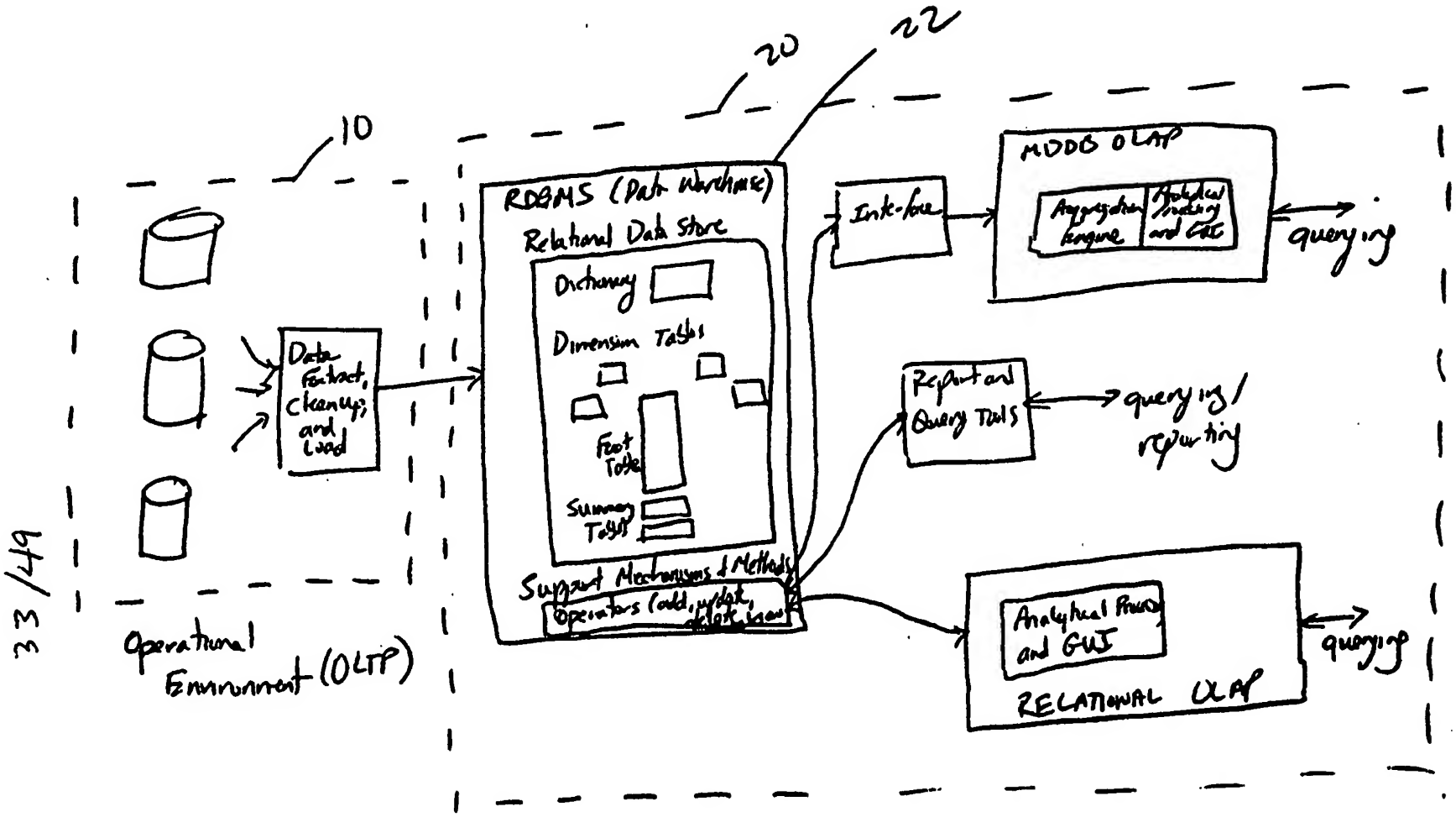

DATA WARE-HOUSE
AGGRE-GETION SERVER
CENTRAL DATA WAREHOUSE
URL
Data Mart
RDBMS
ROLAP
OLAP

Fig. 13



Continuous data	Snap-shots
On-line processed data	Extract processing (copied data)
Normalized data	Data warehouse
	Data marts
	OLAP
	Data mining
	EC-enabled Web servers
	EDI B-2-B Exchange
	De-normalized data

FIG. 14 (PRIOR ART)



33/49

FIG. 15

(PRIOR ART)

CELLAR

Wine	Year	Bottles
Chardonnay	1996	4
Fume Blanc	1996	2
Pinot Noir	1993	3
Zinfandel	1994	9

FIG. 16A

Restrict: operator :

```
SELECT WINE, YEAR, BOTTLES
FROM CELLAR
WHERE YEAR > 1995 ;
```

Result:

Wine	Year	Bottles
Chardonnay	1996	4
Fume Blanc	1996	2

FIG 16B

Project: operator :

```
SELECT WINE, BOTTLES
FROM CELLAR;
```

Result:

Wine	Bottles
Chardonnay	4
Fume Blanc	2
Pinot Noir	3
Zinfandel	9

FIG. 16C

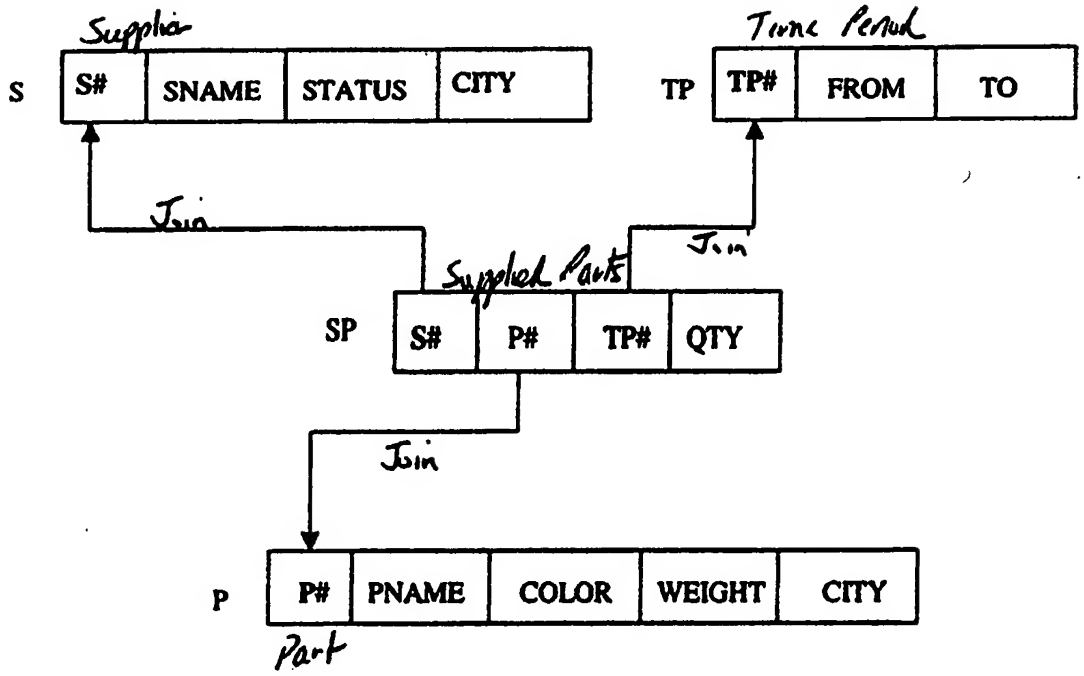

Suppliers
S
S#
SNAME
STATUS
CITY
Time Period
TP
TP#
FROM
TO
Join
Join
Supplied Parts
SP
S#
P#
TP#
QTY
Join
P
P#
PNAME
COLOR
WEIGHT
CITY
Parts

FIG. 17A

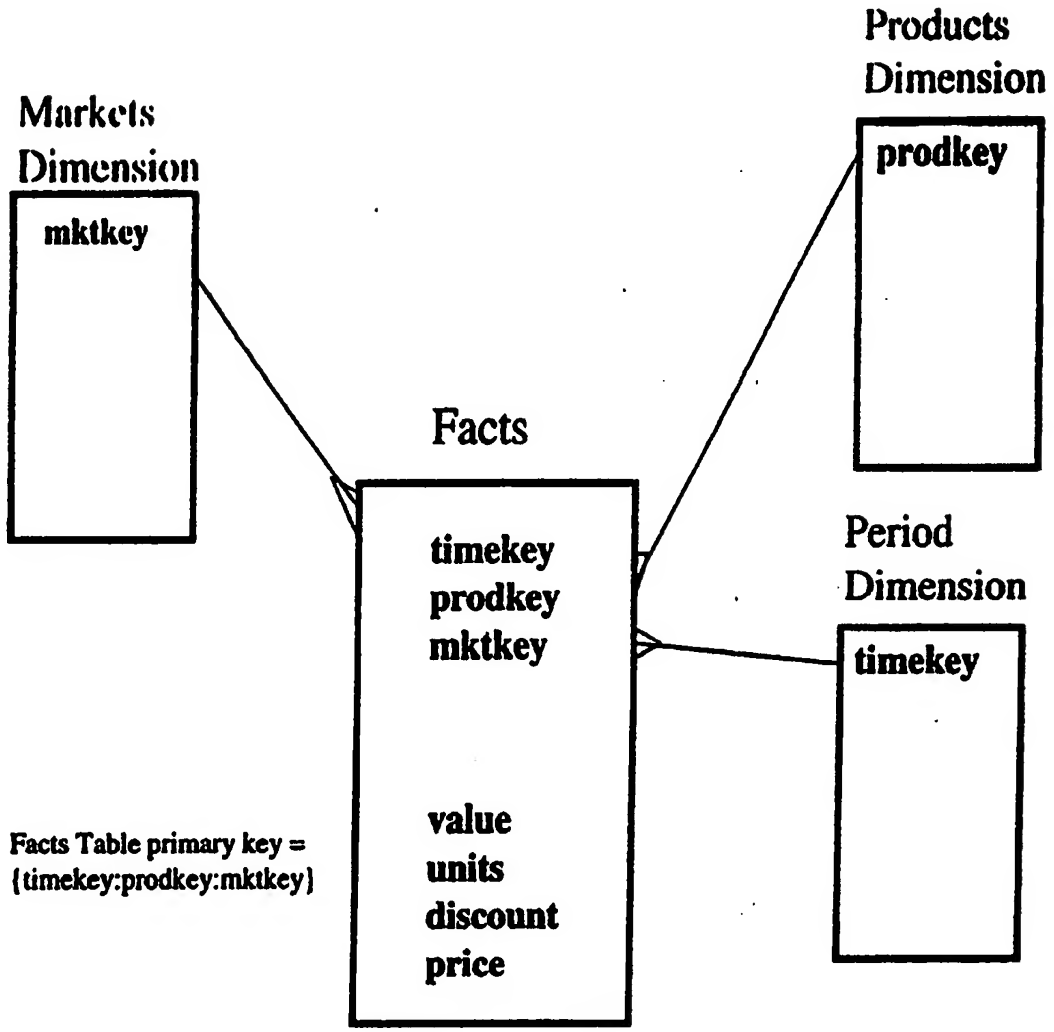

Products
Dimension
prodkey
Markets
Dimension
mktkey
Facts
timekey
prodkey
mktkey
value
units
discount
price
Period
Dimension
timekey
Facts Table primary key =
{timekey:prodkey:mktkey}

FIG. 18A

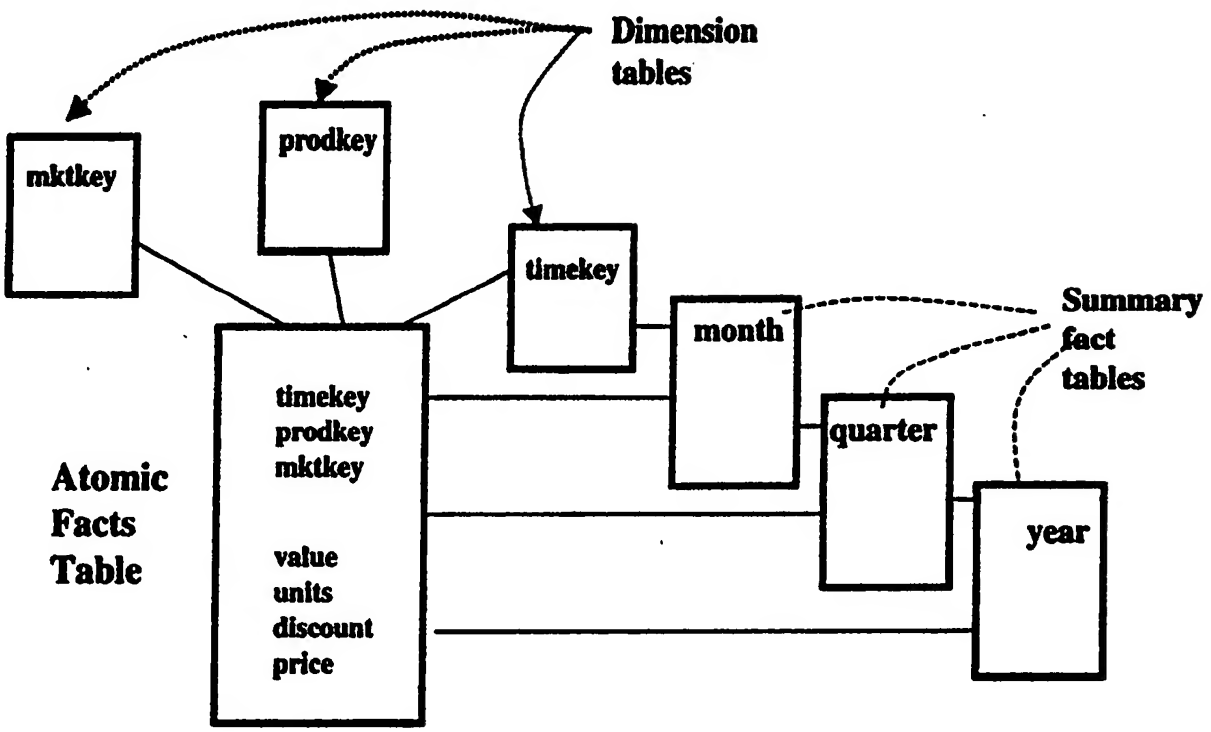

Dimension tables
mktkey
prodkey
timekey
month
Summary fact tables
quarter
year
Atomic Facts Table
timekey
prodkey
mktkey
value
units
discount
price

FIG. 18B

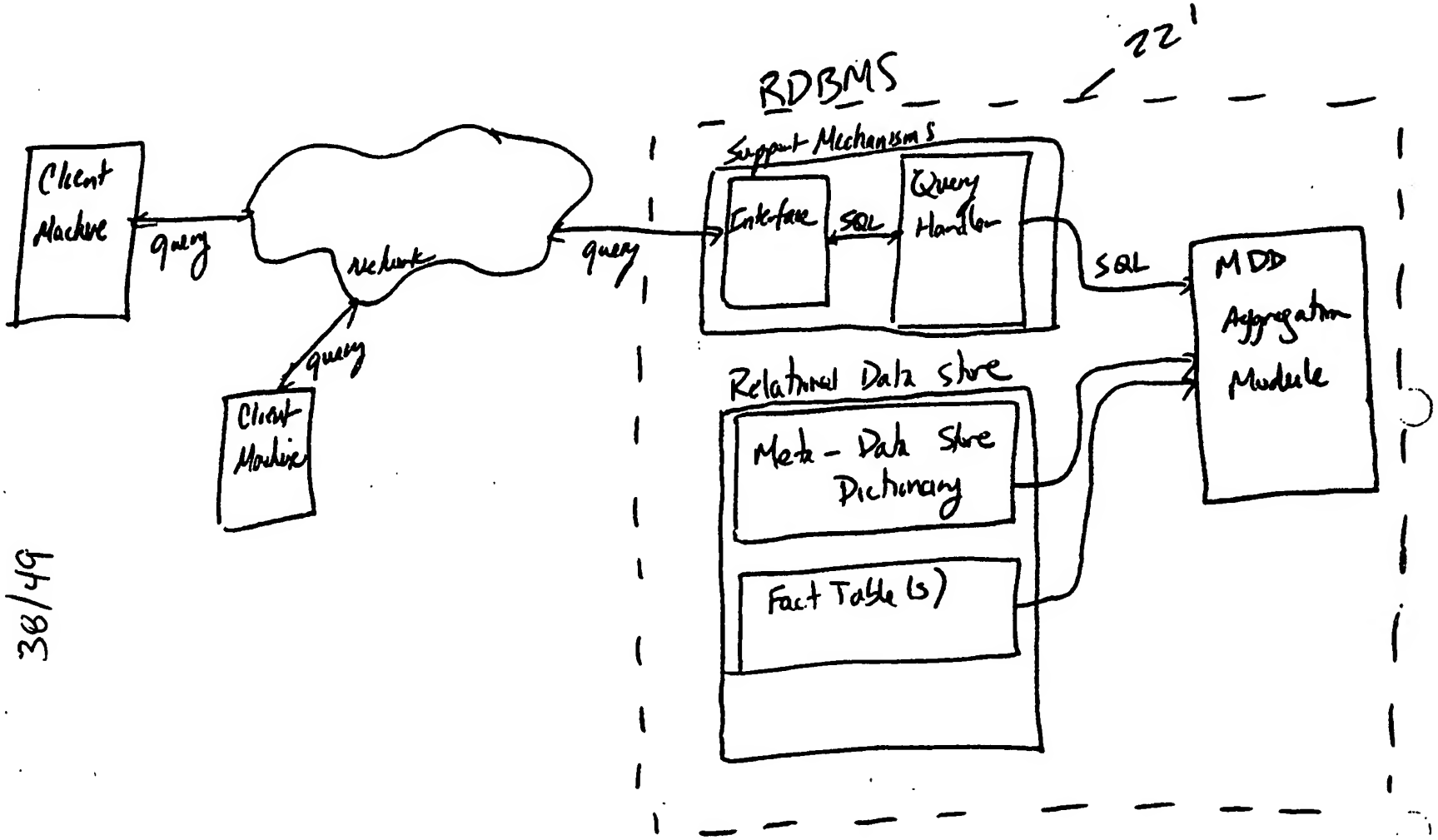

RDBMS
22'
Support Mechanisms
Interface
SQL
Query Handler
Client Machine
query
network
query
query
Client Machine
SQL
MDD Aggregation Module
Relational Data Store
Meta-Data Store Dictionary
Fact Table(s)

FIG. 19A

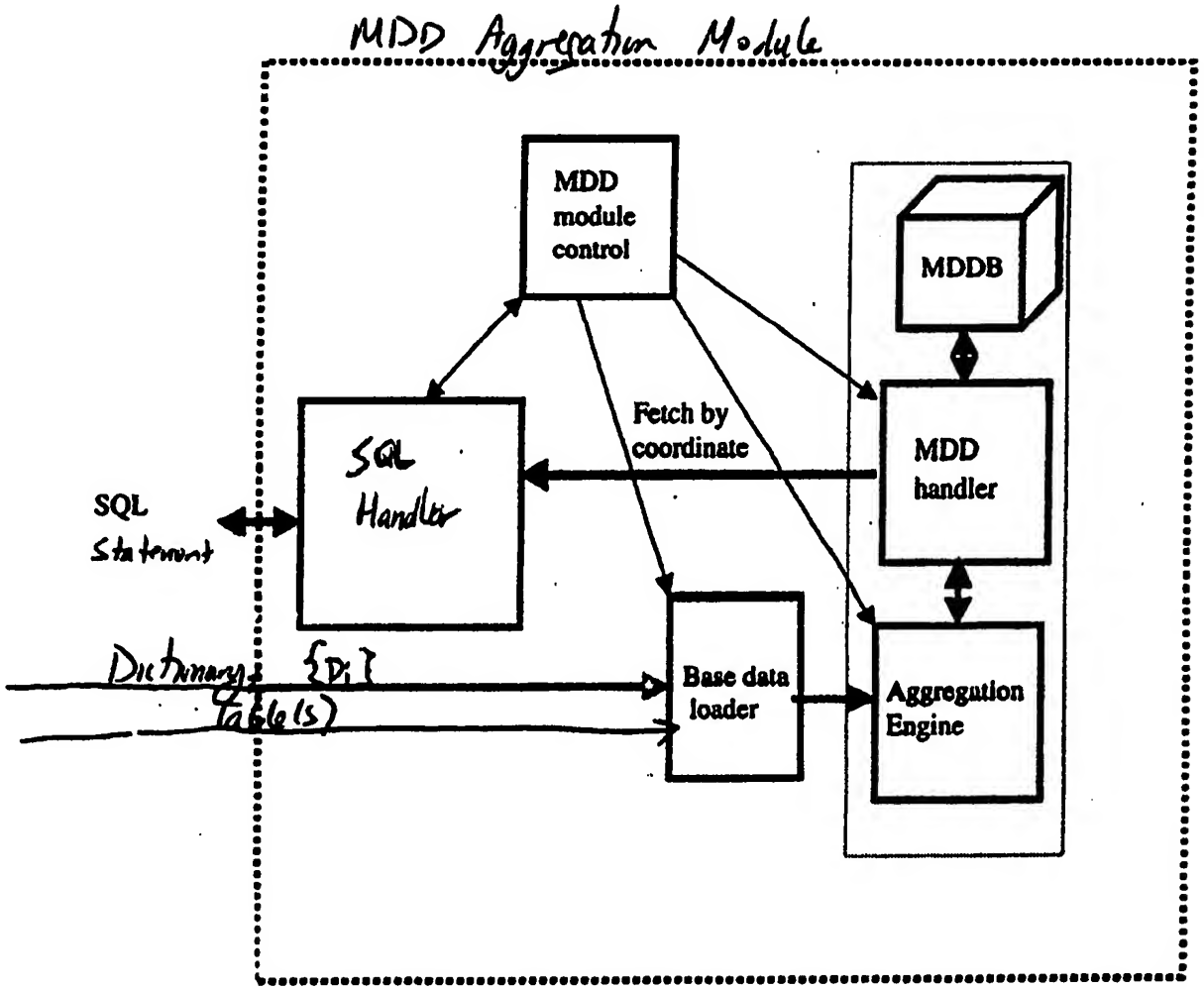

MDD Aggregation Module
MDD module control
MDDB
Fetch by coordinate
MDD handler
SQL Handler
SQL Statement
Dictionary
{Di}
Table(s)
Base data loader
Aggregation Engine

FIG. 19B

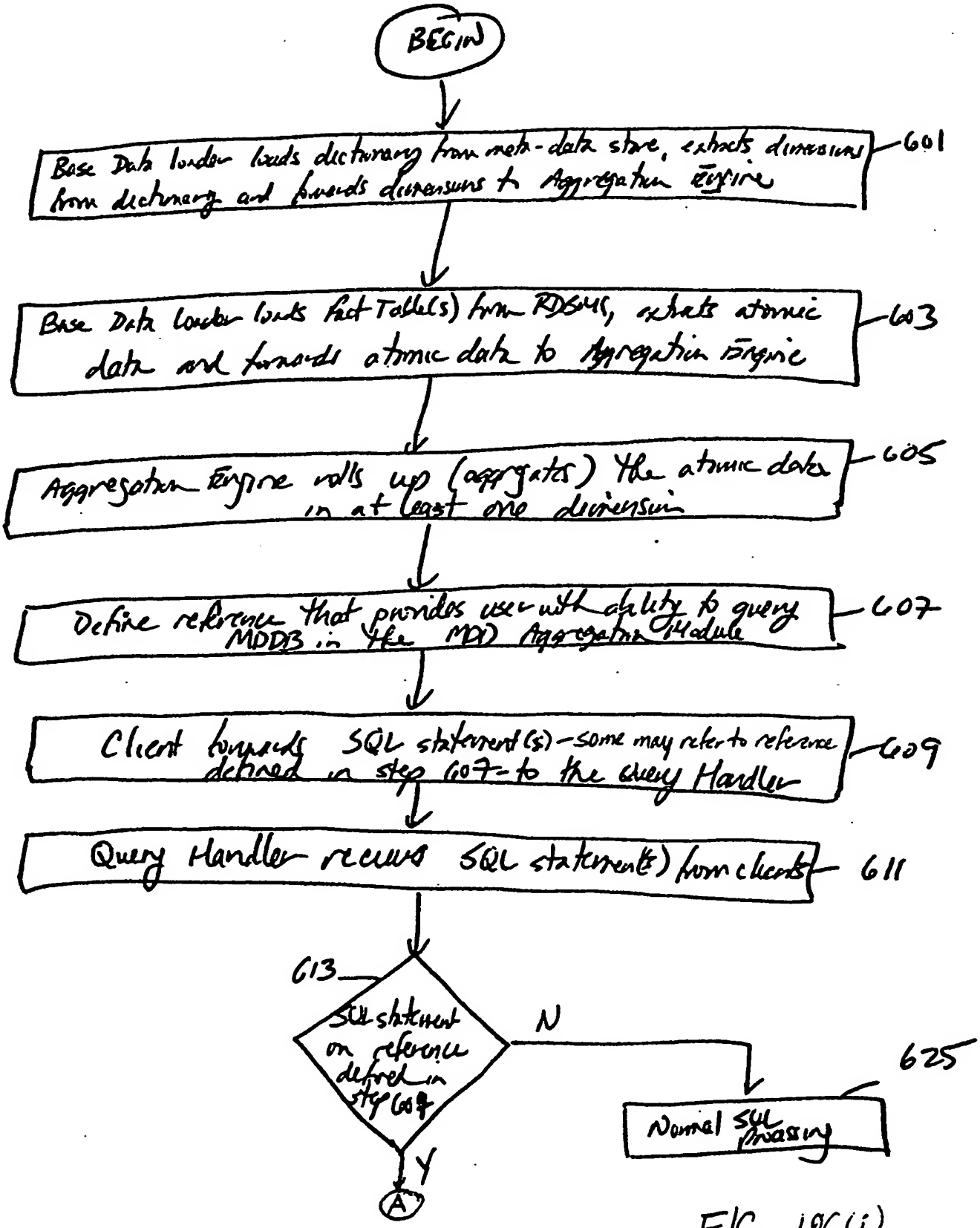

BEGIN
Base Data loader loads dictionary from meta-data store, extracts dimensions from dictionary and forwards dimensions to Aggregation Engine
601
Base Data loader loads fact Table(s) from RDBMS, extracts atomic data and forwards atomic data to Aggregation Engine
603
Aggregation Engine rolls up (aggregates) the atomic data in at least one dimension
605
Define reference that provides user with ability to query MDDB in the MDI Aggregation Module
607
Client forwards SQL statement(s) - some may refer to reference defined in step 607 - to the Query Handler
609
Query Handler receives SQL statement(s) from clients
611
613
SQL statement on reference defined in step 607
N
625
Normal SQL Parsing
Y
A

FIG. 19C(i)

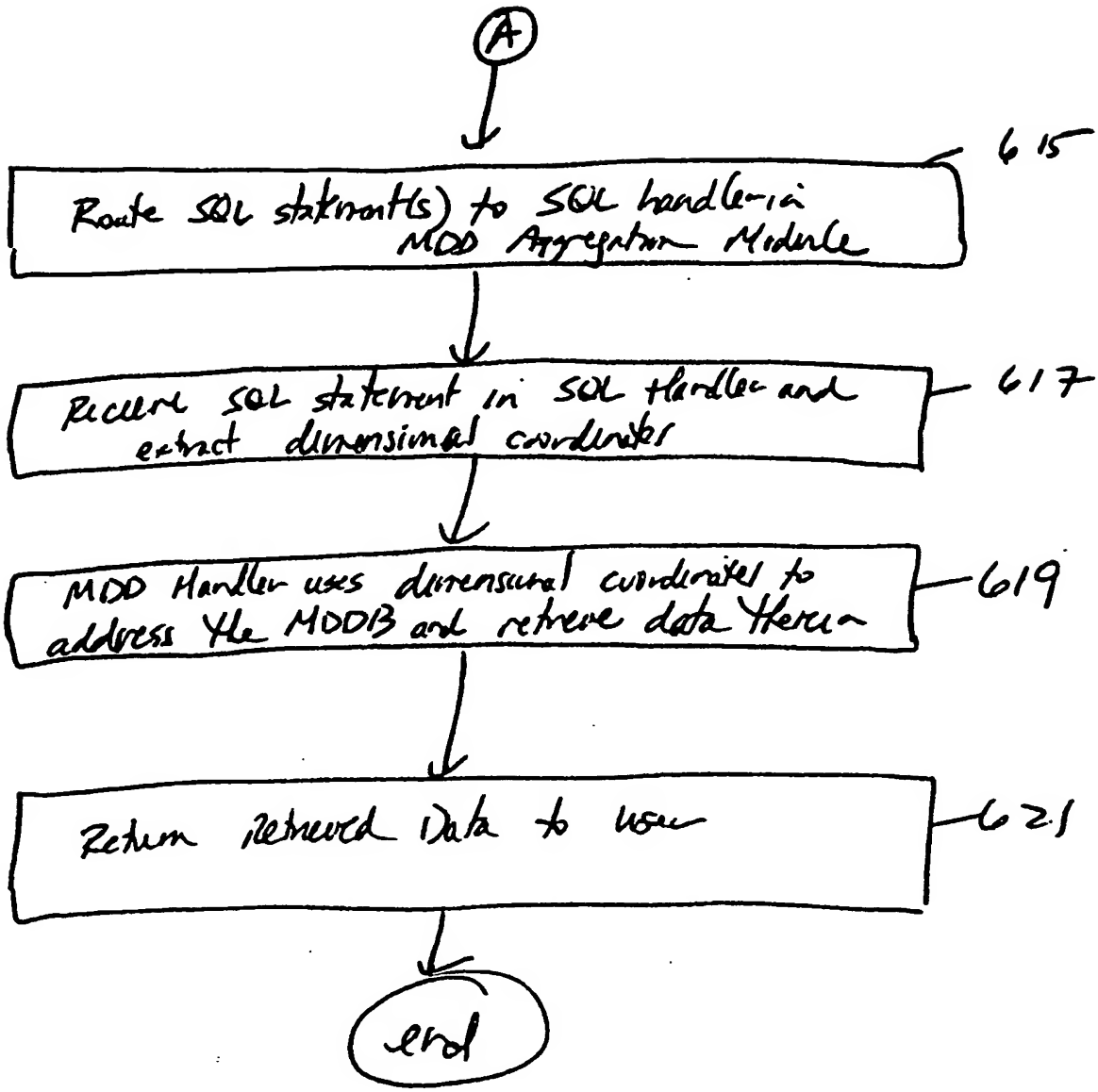

A
Route SQL statement(s) to SQL handler in MOD Aggregation Module
615
Receive SQL statement in SQL Handler and extract dimensional coordinates
617
MOD Handler uses dimensional coordinates to address the MODB and retrieve data therein
619
Return retrieved Data to user
621
end

FIG. 19C(ii)

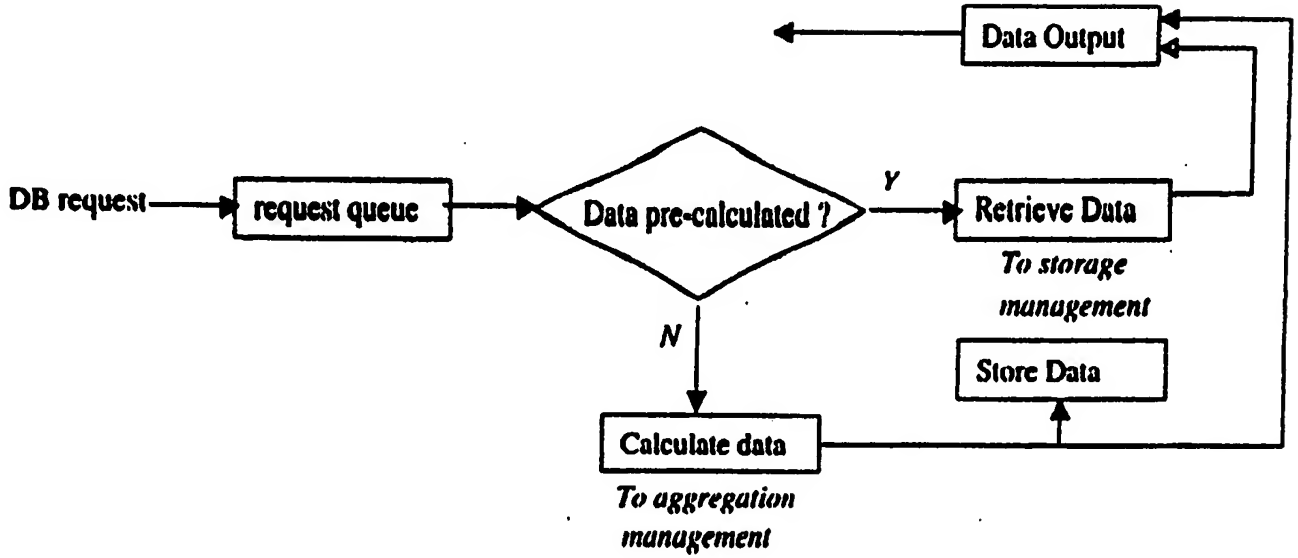

Data Output
DB request
request queue
Data pre-calculated ?
Y
Retrieve Data
To storage management
N
Store Data
Calculate data
To aggregation management

Fig. 19D

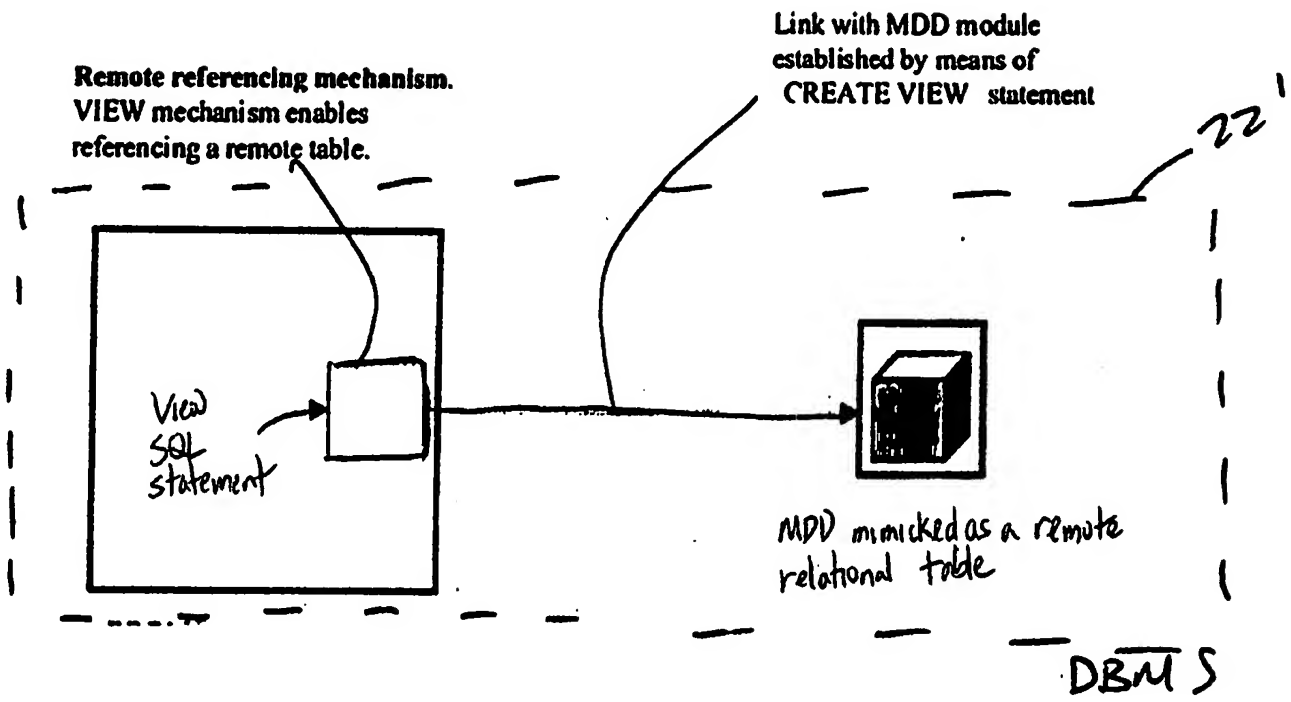

Remote referencing mechanism.
VIEW mechanism enables
referencing a remote table.
Link with MDD module
established by means of
CREATE VIEW statement
22'
View
SQL
statement
MDD mimicked as a remote
relational table
DBMS

FIG. 19E

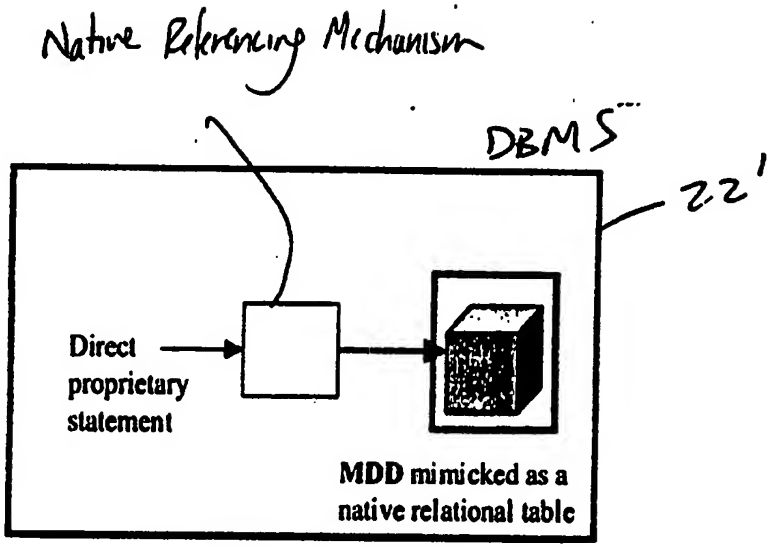

Native Referencing Mechanism
DBMS
22'
Direct
proprietary
statement
MDD mimicked as a
native relational table

FIG. 19F

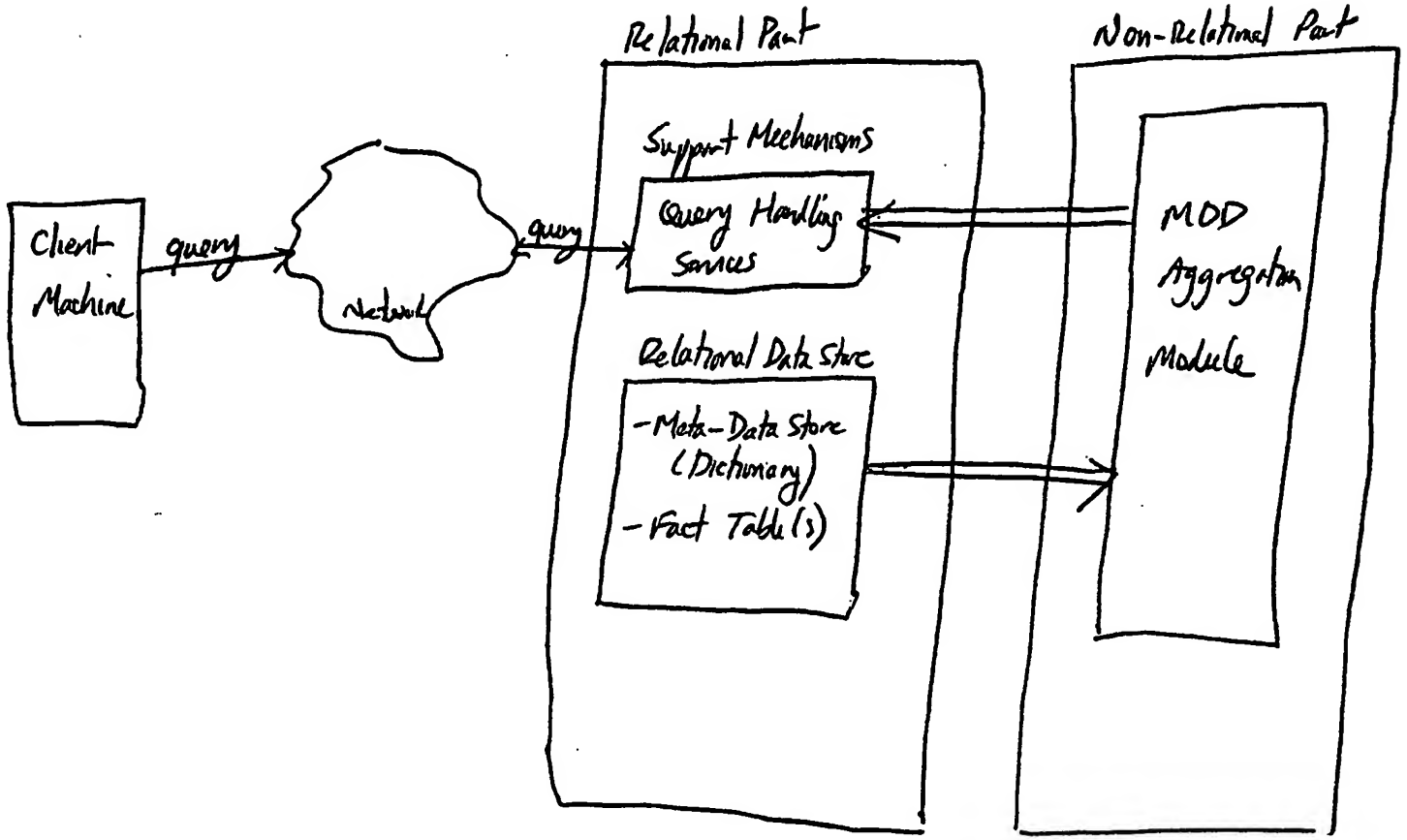
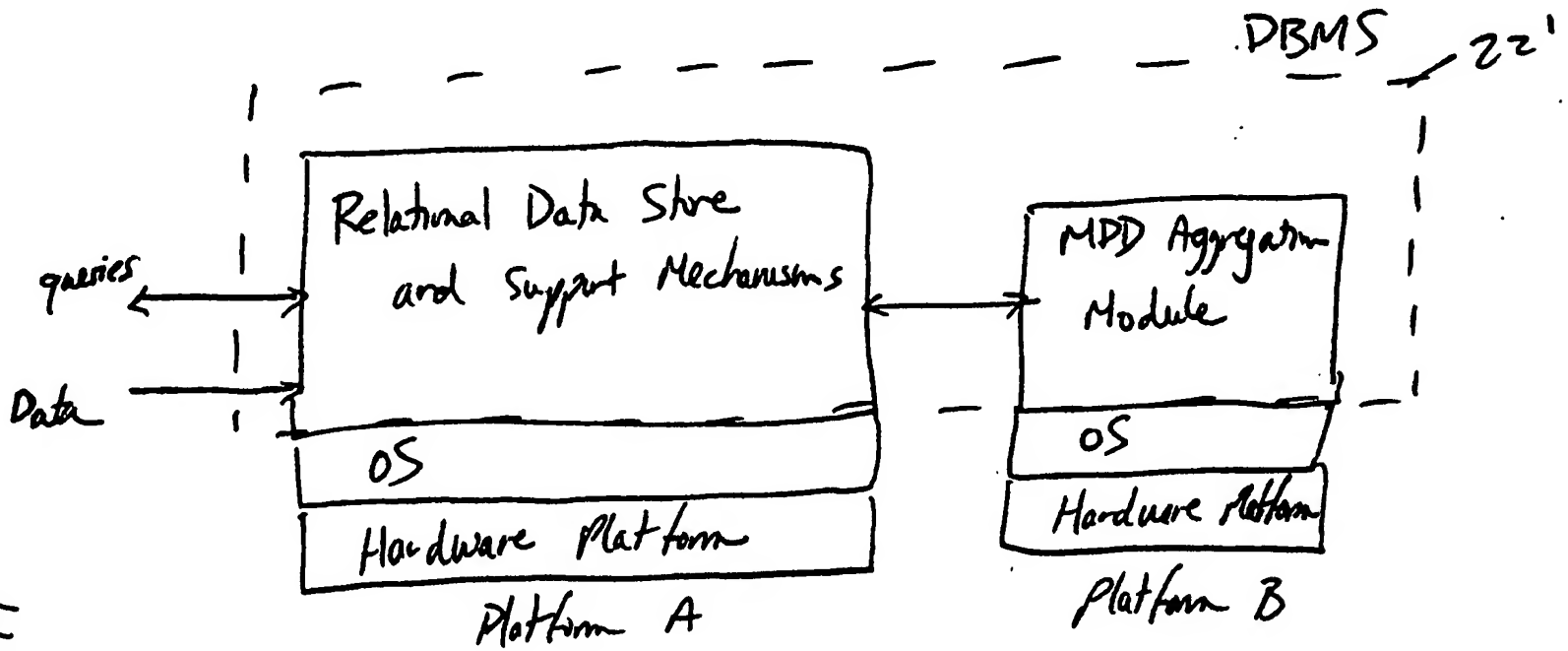

Relational Part
Non-Relational Part
Support Mechanisms
Client Machine
query
Network
query
Query Handling Services
MOD Aggregation Module
Relational Data Store
- Meta-Data Store (Dictionary)
- Fact Table(s)

FIG. 19G


DBMS
22'
Relational Data Store and Support Mechanisms
queries
Data
OS
Hardware Platform
Platform A
MDD Aggregation Module
OS
Hardware Platform
Platform B

FIC. 20A

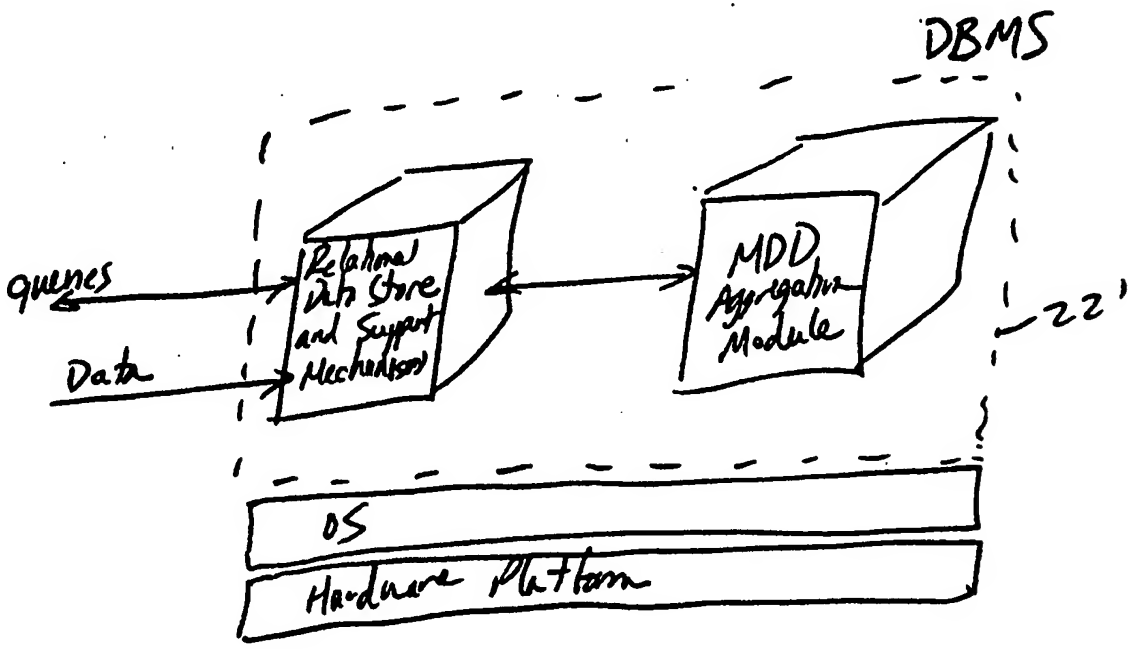

DBMS
queries
Data
Relational Data Store and Support Mechanisms
MDD Aggregation Module
22'
OS
Hardware Platform

FIG. 20B

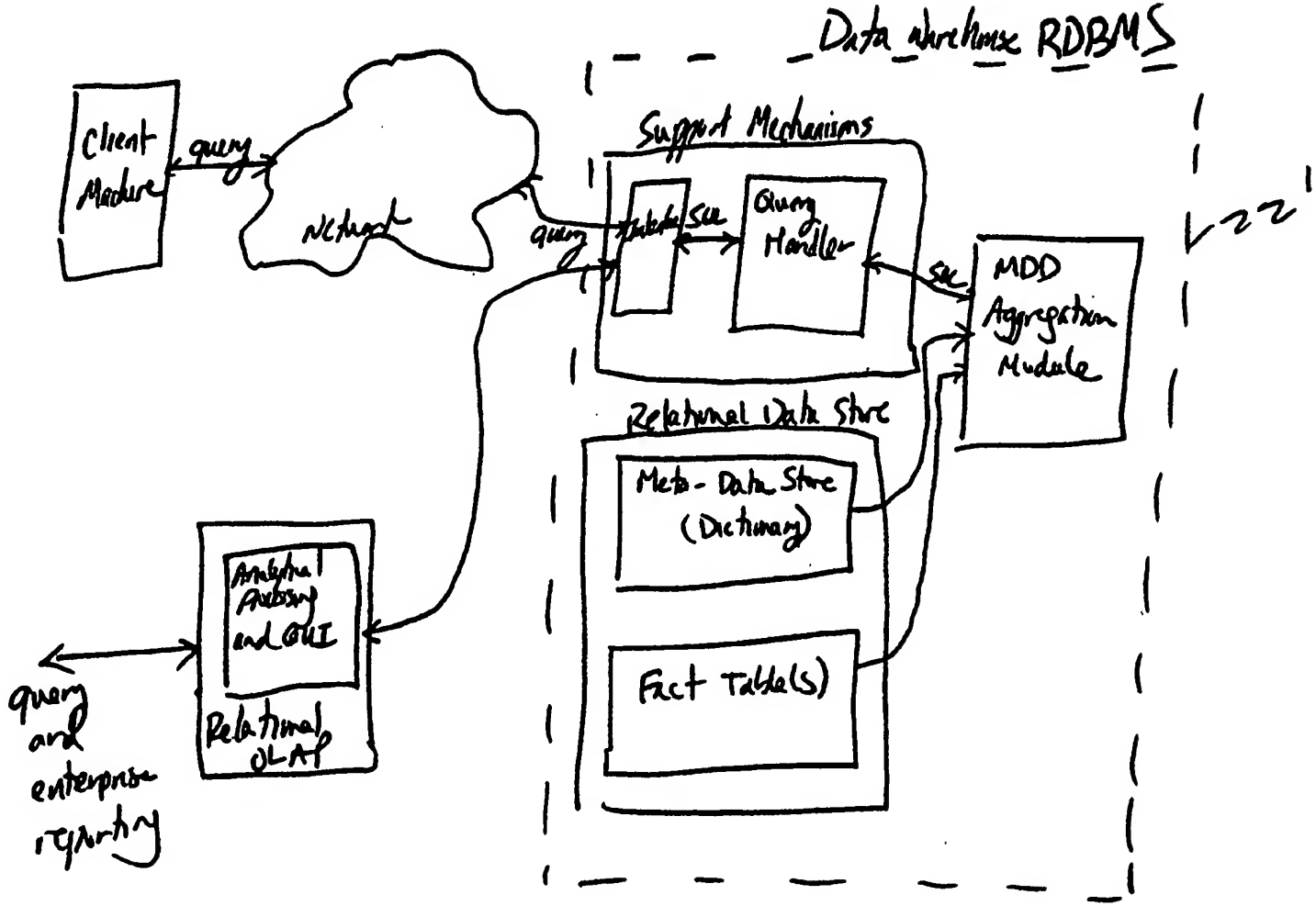

Data Warehouse RDBMS
Client Machine
query
Network
query
Support Mechanisms
Query Handler
SQL
MDD Aggregation Module
Relational Data Store
Meta-Data Store (Dictionary)
Fact Table(s)
Analysis Advisor and GUI
Relational OLAP
query and enterprise reporting
22

FIG. 21

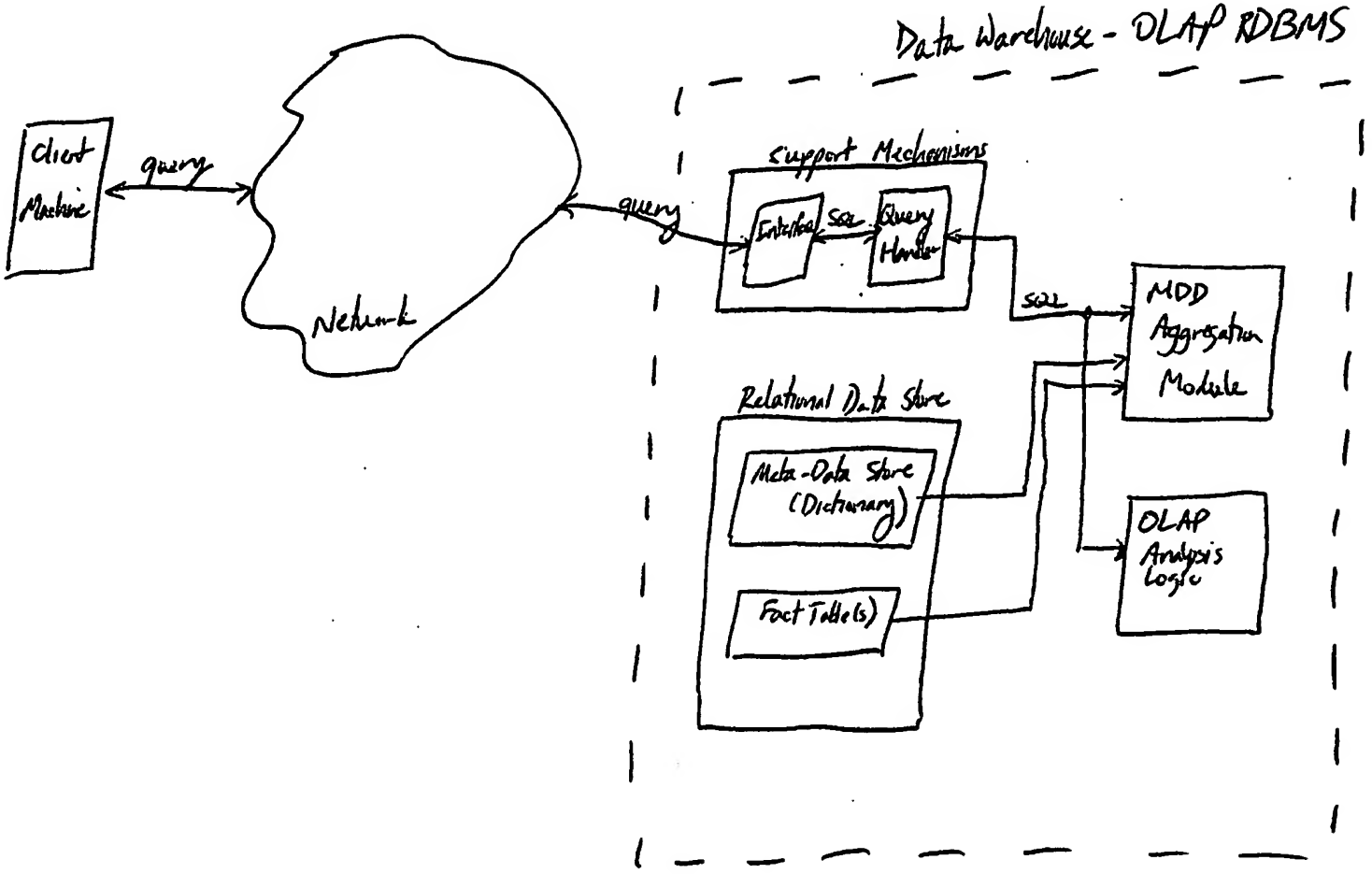

Data Warehouse - OLAP RDBMS
Client Machine
query
Network
query
Support Mechanisms
Interface
SQL
Query Handler
SQL
MDD Aggregation Module
Relational Data Store
Meta-Data Store (Dictionary)
Fact Table(s)
OLAP Analysis Logic

FIG. 22